ANIMAL SCIENCE AND INDUSTRY

Major products and by-products of the animal industry.

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PREFACE

This book was conceived and written while the author was on the Animal Science staff at Iowa State University. It was designed for use in the introductory Animal Science course at Iowa State or at other universities. Most students who take this course will be in their freshman year and will be majoring in Agronomy, Agricultural Education, Agricultural Business, Farm Management or Operation, Pre-Veterinary Medicine, or Poultry, Dairy or Animal Science. Some students in other curricula also elect the course.

The primary responsibility of the book and course is to the majority of students who will work toward a degree and who will take later courses in nutrition, genetics, breeding, selection, management, marketing, and/or meats. For these students an introductory course must develop an appreciation that successful animal production results directly from the application of animal science. Each of the topics is introduced as a "science," rather than as an "art."

An introductory course must also instill in the students an objective and economic attitude toward livestock selection and other phases of Animal Husbandry. Nothing is more practical than an objective approach to problems and a knowledge of the sciences that will solve them.

Organization of this book is different from most introductory Animal Science texts. The material is not divided according to species. Rather, most topics, such as selection of feeders, reproduction, the business of feeding, markets, or milk secretion, include consideration of all species. After teaching the course several times using this type of organization, at the suggestion of Dr. J. V. Whiteman, the author is convinced it is much more efficient.

Principles of nutrition and feeding are much the same for all species. Minor differences, where they occur, are pointed out and explained. Inheritance principles and possible breeding programs are similar for all species. Examples using each species are employed to illustrate the various principles. Selection of meat animals, regardless of species, is based on a single set of objectives and ideals, leading to efficient meat production. Marketing, likewise, is essentially the same for all species. Cattle and sheep raisers use the same markets as hog farmers, and the same factors influence market supplies and prices of hogs as affect cattle and sheep supplies and prices.

The chapter sequence should not be considered particularly important. Considerable cross-referencing among chapters and sections will permit use

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Some of the most valuable help came from men who teach or administer introductory Animal Science courses at other institutions and who were asked by the publisher or author to review the outline, portions of the material, or the entire manuscript. Their advice and cautions have been appreciated, and their suggestions for improvement have been implemented where feasible.

Many of the preliminary line drawings were prepared by my wife. An attempt has been made to cite the source of illustrations, tabular data, and other such material where it appears, and to give proper credit to individuals and institutions. If proper credit has not been given, it is certainly unintentional and sincerely regretted.

D. A.

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LIVESTOCK IN AMERICAN AGRICULTURE

Food is the primary product of agriculture. Natural fibers, such as wool, mohair, and cotton; certain pharmaceuticals, plastics, synthetic fibers, and oils; and leather are also products of agriculture highly important to the American economy and society. Technology has developed products of nonagricultural origin that can replace or supplement many of the latter items, but satisfactory substitutes for agriculturally produced *foods* are yet to be developed.

Plant and livestock products—cereals, vegetables, fruits, meat, milk, and eggs—contain the essential nutrients for human life in a form that provides enjoyment and satisfaction difficult to describe or copy. We would confidently challenge the chemist to duplicate, without agricultural products, a medium-rare sirloin steak, roasting ears covered with butter, icy watermelon on a hot afternoon, bacon and eggs on a frosty morning, or rich, chocolate ice cream.

The proportion of *animal* products in the American diet has increased and this trend will probably continue. A higher net income and level of living have meant greater expenditures for meat, and dairy and poultry products. At the same time, a decrease in the energy needs of the average American, because of automation and shorter working hours, has lowered the consumption of high caloric foods such as potatoes, bread, and cereals. More of the plant products are being fed to animals to produce the animal products Americans desire and can now afford.

For a comparison of the American level of living with that of citizens in many other countries see Table 1-1.

A. The Agricultural Economy

The Agricultural Revolution, beginning in 1837 with the invention of the steel plow and continuing through the twentieth century with remote controlled tractors, chemical cultivation, and automatic feeding systems, is significant for all—since everyone consumes food and uses other agricultural products. Acres have been added for production by drainage of swamps, irrigation of arid regions, and clearing of timber and scrub from

Table 1-1 Approximate Net Food Supply per Person in Certain Countries*

	Calories per day	Protein gm./day	Animal protein gm./day	Meat[1] lbs./year	Eggs[2] per year	Milk[3] lbs./year
United States	3130	93	66	207	351	609
France	2920	98	52	163	193	474
United Kingdom	3290	87	52	156	246	474
Japan	2210	68	18	13	70	68
U. of South Africa	2580	73	30	95	53	203
Australia	3210	92	60	257	193	406
India	1950	52	6	4	–	135
Argentina	3040	95	52	220	123	271

*Food and Agriculture Organization of the United Nations *Production Yearbook* 14 245 249 Figures are for 1959 or 1960 or one year periods between 1958 and 1960

[1] Carcass weight of red meats poultry and game excluding slaughter fats

[2] Converted from kilograms assuming 57 gm per egg

[3] Whole milk equivalent calculated from kilograms milk protein assuming 3 25 per cent protein in whole milk.

potentially good pasture land New varieties of crops and strains of live stock provide more food per acre and per animal unit. Mechanical equipment and cheaper, more available power have made each farm worker more efficient and more productive

These and other developments have made it possible for *fewer farmers* on *fewer farms* to feed more people at a higher level Table 1-2 illustrates the decrease in the number of farms and the corresponding increase in the number of people each farm worker supplies This has occurred while the quality of the American diet has increased considerably, with an estimated rise of 20 per cent in the proportion of animal products consumed per person.

With relatively fewer people engaged in *production* of agricultural products, the whole concept of agriculture has changed Agriculture now includes many people involved in processing and distributing agricultural

Table 1-2 Approximate Number of Farms and Efficiency of Farm Workers Since 1920*

Year	Millions of farms	Persons supported by one farm worker
1920	6.5	8.2
1930	6.3	9.7
1940	6.1	10.8
1950	5.4	15.4
1960	3.6	26.0
1962	3.3	28.0

*AMS and ARS USDA.

products; in services related to agriculture, such as production and sale of feed, farm equipment, buildings, and fertilizer; and in educational, promotional, and regulatory work. The decreased numbers in production does not mean this group is less important. Each individual in production is more important, because of the increased size of each farming unit and the dependence of more people on that unit for food.

A very important characteristic of the agricultural economy is the relative *inelasticity* of demand for food products. Demand (consumption) is not greatly altered by changes in supply and price. When there is a shortage of food, prices skyrocket. Consumers want and need a stable food intake and will compete vigorously for the available food. Likewise, in periods of overproduction and food surplus, consumption does not increase significantly and food prices drop markedly.

This characteristic of relative inelasticity, coupled with the perishability of many food products, helps explain much of the attention given to slight changes in yearly production of farm commodities.

1.1 Change

About the only permanent characteristic of American agriculture is the presence of *change*. Previous paragraphs have described shifts in level of living, as well as in numbers of people engaged in production, distribution, and services. Significant changes are also occurring in the production units themselves. Though over 95 per cent of the farms and ranches are still family operated, the operations are materially different than a generation or two ago. Each production unit, on the average, is *larger*, *more highly specialized*, and more *highly capitalized*. Operators of production units have higher "fixed" costs, such as taxes and depreciation on equipment.

Most ranches in grazing areas have always been specialized in cattle or sheep raising, because their only feed was roughage. But in other areas of the country, diversification was universal. Most farmers raised nearly every kind of livestock, in addition to forages and grains. This is not true today.

Although there is the obvious advantage of less risk in diversified operations, the current trend toward specialization is prompted and encouraged by numerous factors. If a producer is to take advantage of expensive labor-saving and time-saving equipment, he must make full use of it. To justify a completely automatic cattle feeding system, for example, he must continually feed large numbers of cattle, which may use all of the feed, buildings, and capital available. To employ modern milk handling equipment efficiently, he must milk a relatively large number of cows. Increased technical knowledge also makes it desirable for a farmer to specialize. He must master certain fields so he can effectively compete with his neighbors in production efficiency.

An indication of the increased specialization on farms is the fact that

farm families currently buy about 60 per cent of the food they eat, much more than farm families in the 1800s Few families now keep hens for eggs unless they are in the commercial egg business, or cows for milk unless they sell market milk Capital and labor can usually be better employed in larger enterprises on the farm

How much capital does it take for the average farm operation? The United States Department of Agriculture (USDA) recently reported $35,000 as the average, but it is not uncommon for a commercial farm operation to be using $200,000 to $500,000 capital This means a great responsibility for each farm operator He must have all the experience and training possible to use and handle this responsibility wisely

A young man starting farming at the present time must realize the presence of certain "social" factors which are somewhat peculiar to this last half of the twentieth century All farmers today have higher fixed costs than was true during the 1930's Taxes are higher because the *population demands* that the governments—local, state, and federal—provide more services and insurances Yesterday's conveniences are today's essentials Automobiles, telephones, television sets, radios, and other home appliances are all considered essential This dictates that a farmer receive a certain amount of cash income per year in order to have such "essentials" and also to continue farming Profit in spendable dollars is necessary

In the early part of the century these various conveniences were not known Taxes were lower in relation to average income because the demands on government were less It was therefore less essential that a farmer make a good profit in any one year He could weather several consecutive bad crop years and several livestock losses without having to give up farming completely, a situation no longer possible

Today most young farmers need quick income Because they are short on capital, they need cash for current expenses Interest payments, as well as payments on principal, must be made

Further evidence of the apparent need for spendable and quick income by farm families is the fact that approximately 25 per cent of the farm wives are currently employed off the farm

1.2 Land

Soil is the basis of all agricultural production The amount, topography, fertility, and location of land available for production is of concern as the human population continues to expand

Since 1900 the total acreage in crops and pasture has generally increased to the West, the Corn Belt, and the lower Mississippi valley, but crop and pasture acreage has decreased in many parts of the East The acreage occupied by cities, towns, rural residences, industrial plants, highways, airports, reservoirs, recreational areas, and other facilities has increased

enormously with the population growth, especially in the eastern states, the west coast states, and around the Great Lakes.

According to the 1958 Yearbook of Agriculture, *Land,* the following changes occurred in land use each year, on the average, between 1945 and 1954.

Urban areas	395,000 acres increase
Highways	78,000 acres increase
Airports	5,000 acres increase
Reservoirs	360,000 acres increase
Railroads	7,000 acres decrease
Net total	831,000 acres increase

Since these figures are averages for 1945 to 1954, they do not include land consumed by the Interstate Highway System approved by Congress in 1957. Nor do they include current increases in parks, military sites, and wildlife areas. The total increase in land acquired for these special uses probably approaches a million acres per year, and may accelerate due to our geometrically expanding population. It should be noted that much of the land converted to special uses is tillable land, so considerable food producing resources are lost each year.

1.3 What is Agriculture's Production Goal?

Estimates of United States population are:

1963	188,000,000 people
1975	225,000,000 people
2000	300,000,000 people

With this anticipated increase in population in the United States with no allowance for changes in per capita consumption, the production of eggs, meat, and milk must be increased at least 20 per cent between 1960 and 1975. But if there is to be a continued increase in *per capita consumption* of these products, the combined result becomes a total increase in demand for animal products of approximately *40 per cent.* This must be met with no anticipated increase—and probably a decrease—in cropland. Such a projection illustrates a need for almost *doubling* the 1960 agricultural output in the United States by the year 2000.

1.4 How Will the Goal Be Met?

In the last thirty years[1] a *decreasing* number of farm workers, working *fewer* hours, have *increased* farm production in the United States faster than the population has increased. Farm production has gone up about 80

[1] USDA and Department of Commerce, Economic Report of the President, Jan. 1961.

per cent, man hours of farm labor have declined 50 per cent Efficiency of farm production—farm output *per* man hour—increased *over 200 per cent*

Estimates for 1961[2] indicated that the United States farm workers, representing under one fourth of one per cent of the world s population, produced almost 30 per cent of the red meat and about 20 per cent of the fluid milk produced in the world that year

Will American agriculture continue to meet the challenge during the remainder of the twentieth century? If so, *how?*

Initially we will see increased application of presently available knowledge in crop and livestock production This alone will go far toward meeting the goal There could be fewer exports and more imports Some may suggest that the number of horses will continue to decrease, but this will probably not happen In fact, light horses, dogs, and other pleasure animals will undoubtedly increase, using more feed than currently

Crop yields will go up Better and more highly adapted varieties will result from continued selection and breeding programs Fertilization will increase and fertilizers that are more efficiently used by plants will be developed Irrigation will become feasible on more farms as potential yields rise and drouth becomes more expensive These developments, plus possible use of soil conditioners and new tillage methods, will encourage continuous cropping—production of grain year after year on the same land Hydroponics—growing crops in a water solution of nutrients without soil —is a further possibility

There will be continued increases in output per breeding animal More potential breeding animals will be checked for production efficiency before being accepted in a herd Artificial insemination will increase, spreading more widely the merits of top quality sires The reproductive cycle may come under human control and be speeded up, so top quality females can produce more offspring

We will learn more about nutrition and will balance rations with greater precision Nutrients will be synthesized more economically and critical nutrients will be more consistently added to feeds, reducing nutritional deficiencies Coarse, fibrous feeds may be pretreated to increase utilization

Other developments, unimagined today, will also have great impact in helping the American farmer meet the challenge

B Livestock Distribution

1.5 Livestock Density

Livestock density—the number of animals per square mile—is almost completely dependent upon feed supply Transportation costs of moving

[2] Foreign Agricultural Service USDA

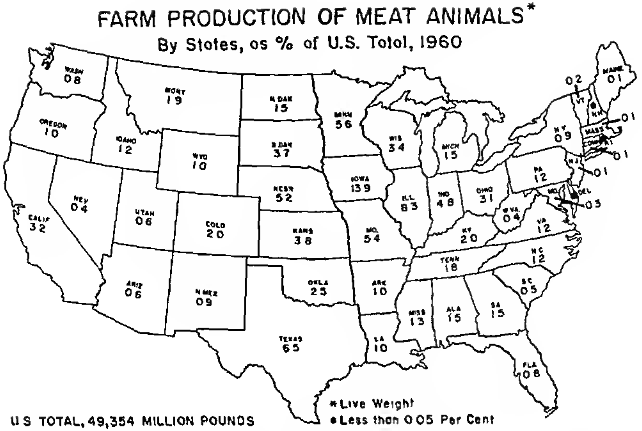


Figure 1-1. Relative production of meat animals in various states is indicated above. Note that Iowa and the surrounding states make significant contributions to the country's supply. Though some large states, such as Texas, produce large quantities, livestock density may not be as great as in some smaller states, such as West Virginia or Rhode Island. (AMS, USDA)

feed from one area of the country to another are so great, it is almost economically essential that livestock be raised where there is adequate feed. Anything which affects feed supply or production, therefore, will indirectly influence livestock density and meat, milk, and egg production.

More feed, such as grain and hay, can be grown on flat or gently rolling land than on hilly or mountainous areas. Because steep or rough land is subject to erosion, it cannot be effectively used for producing row crops or grains, which are necessary for the highest yield of animal feed per acre. Such land is best suited for timber and grazing.

Rainfall and soil fertility are important for the growth of feeds. Water is essential for plant metabolism and growth and the soil must supply plant nutrients. Soil structure, which is partially dependent upon temperature and decay of organic matter, has an effect on feed production. The soil must be loose enough to provide aeration and good drainage.

A combination of these various factors—level or gently rolling topography, adequate rainfall, well-drained and fertile soil—are essential for maximum livestock feed production. Such a situation exists in the Corn Belt of the United States, which has very intensive livestock production. Iowa, for example, has the densest population of meat animals, producing more red meat per square mile than any other state in the country. Adjoining states rank high in this respect because of similar soil fertility, topography, rainfall, and other climatic conditions. This is illustrated in Figure 1-1.

The same situation is true for smaller concentrated farming areas in the irrigated valleys of New Mexico, Arizona, California, and other states Here water is supplied by irrigation, but the soil is rich and level, and the intense crop production is conducive to intense meat and milk production

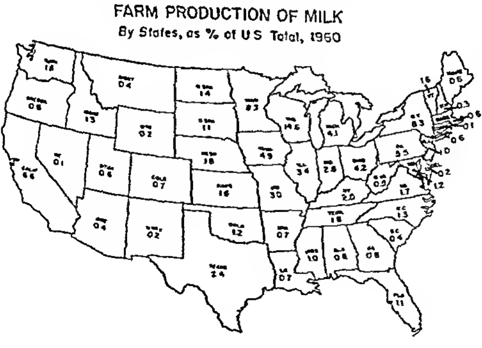
Direct effects of climate and location on the animals should also be considered Certain species or breeds of livestock are more adapted to the temperate conditions in the central United States, than to the semitropical or tropical climate near the Gulf of Mexico or in Central or South America Most breeds of cattle have little ability to perspire to eliminate excess body heat In a semitropical or tropical environment their production efficiency is tremendously lowered

High temperature and rainfall are conducive to a large number of parasites and insects which hinder livestock growth and performance Where winters are not severely cold, various parasites and insects interfere more with livestock performance because they can reproduce continually

Altitude and topography also need to be considered Sheep, sure-footed and able to graze closer to the ground, are more adapted than cattle to mountainous and hilly terrain Likewise, they are apparently more adapted to a higher altitude and lower atmospheric pressure

Livestock density is usually not influenced by the convenience of certain markets Most often the reverse is true, especially in the case of meat animals Markets have developed near livestock production centers, or in a

Figure 1 2 Relative milk production in various states Note production is closer to population centers than is true for meat animals (AMS, USDA)



logical location between the producing and consuming areas. Milk production was formerly concentrated near large centers of population, because of the perishability of milk. With improved transportation and preservation, however, this is less true today (Figure 1-2).

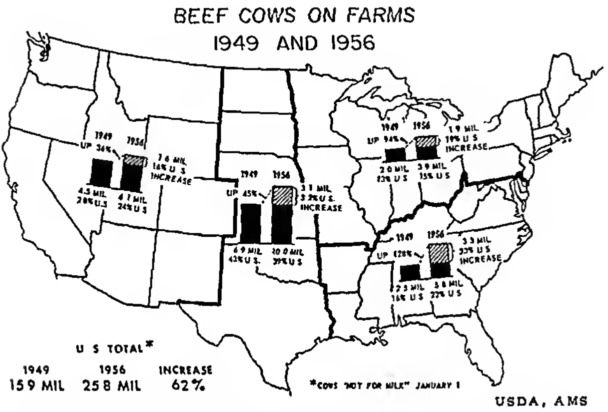


Figure 1-3. From 1949 to 1956 beef cows in the United States increased 62 per cent, or almost 10 million head. One third of the total increase occurred in the Southeast, where numbers of beef cows rose 128 per cent in only six years. (AMS, USDA)

1.6 Shifts in Livestock Density

It is impossible to list all the reasons for changes and shifts in livestock population within and among certain areas of the country. But let us look at some of the changes occurring in recent years and try to explain them.

A most drastic change was the tremendous increase in beef cattle in the southeastern states from 1949 to 1956 (Figure 1-3). Without regard to the former use of this area, we recognize today that the southeastern states have relatively good topography, a soil that can be fertilized, adequate rainfall for grass production, and that certain beef breeds are adapted to this latitude.

History tells us that the area was first used for intensive cotton production. The high price for cotton at the time these states were first settled made it the most profitable crop. For more than a century nearly all who farmed were cotton farmers.

In the early 1900's, however, there developed a tremendous infestation of boll weevil. There was no known method of combatting or controlling

this terrible pest and it covered the entire Southeast, destroying crop after crop of cotton. Many cotton farmers went into great debt.

Because of the boll weevil and other factors, cotton production dropped and prices went up. It become economically feasible for farmers in the southwestern United States to raise cotton. The boll weevil was not common in the area because cotton was a new crop there. Soon boll weevil control techniques were developed, as were varieties of cotton adapted to the Southwest.

Even with control of the boll weevil, much of the Southeast could not get back into cotton production. Cotton had been grown for so many years on most farms that soil fertility was depleted. Many farmers and ranchers shifted to livestock. They learned they could increase soil fertility and structure by planting grasses and raising cattle.

About the same time, ranchers in the western United States experienced several successive years of severe drouth. They looked longingly at the high rainfall in the Southeast, learned that grasses grew well there, and that potentially a cow and calf could be grazed per acre. Many ranchers migrated from the western states, from such states as Montana and Arizona, to the potentially good grazing land in the Southeast. Today we see an intense beef cattle population in this area.

The number of milk cows in Florida increased over 30 per cent from 1952 to 1960. Reasons for this sharp increase probably include the rapidly expanding human population, better forage production, and development of facilities for handling dairy cattle in the warm climate.

Another relatively recent development is the increase in commercial cattle and sheep feeding in the West. There are several reasons: (1) increased human population and meat consumption in these areas, (2) irrigation, permitting increased crop production, (3) use of commercial fertilizers, and (4) specialization among cattle feeders. The last three factors have allowed western feeders to produce beef efficiently and compete effectively with Corn Belt feeders.

The impact of this increased feeding in the West has been felt in other parts of the country. The Corn Belt cattle feeder has noticed more competition for feeder cattle grown in the western range states. Western feeders are willing to pay good prices for these feeder cattle. So the Corn Belt feeder has had to look in other directions, perhaps to the Southeast, or to cow herds in the Corn Belt for feeder cattle. Accompanying this change has been an increase in size of certain livestock markets in western areas, and a decrease in receipts at some midwestern markets.

Recently southern farmers have developed more confidence in livestock production and there have been increased numbers of poultry and hogs grown and fed in the southern states. With the development of corn hybrids more adapted to the South, grain supplies have increased. Labor in these states is cheaper than in the traditional feeding areas of the Corn Belt

Another reason for this change is the willingness of various organizations such as feed companies to finance poultry and hog-producing operations, providing both management and marketing help.

We have reviewed specific cases in which centers of livestock production have changed as the result of various economic and technical developments, and because of shifts in human population. Such developments and population shifts will continue causing changes in the relative advantage of growing livestock in certain areas. Since growing livestock is a business and must be finacially successful to be continued, a person involved in any of its phases needs to be aware of signs indicating economic changes of importance to him.

C. Livestock Adaptation

Various characteristics of livestock influence the adaptation of different species to specific areas or production units. The kinds of feed they can utilize and their susceptibility to certain stresses—extreme temperatures, parasites, and diseases—largely determine the part of the country where each species will flourish. Other characteristics are important, however, in determining the suitability of each species for certain production units.

1.7 Digestive System

Poultry and swine have digestive systems similar to that of a human. Their relatively small, single-compartment stomach cannot handle large volumes of bulky forages, so these animals (Figure 1-4) depend primarily on concentrated grains and similar feeds. Mature sows do use considerable forage, but growing swine and poultry and laying hens cannot consume enough forage to provide the energy they need.

Figure 1-4. Hogs and poultry get most of their energy from concentrated feeds. (Wal nut Grove Products Co. and Iowa State University)

Cattle, sheep and goats are designed for forage utilization A large four-compartment stomach provides ample capacity for grass and hay The first three compartments prepare fibrous forage, by means of bacterial fermentation and thorough grinding for efficient utilization

Though cattle and sheep can grow mature, and reproduce on forage alone, those being fed for slaughter are usually given high proportions of grains to speed up growth and cause deposition of fat within muscle groups Dairy cattle fed for high milk production also need high proportions of grain in their rations

It is apparent, therefore that beef cow herds and ewe flocks are well adapted to grazing areas that cannot be used for grain production Poultry and swine are raised, cattle and lambs are fed, and dairy herds are kept where high energy grains are produced abundantly

Animals which use mostly concentrates are also more adapted to intensive feeding operations in which *all feeds are purchased* Grains and other concentrated feeds can be hauled and stored in less space and fewer pounds are needed to produce an egg or a pound of meat than when forage is used

1 8 Foraging Ability

Goats have the ability to graze over rough terrain, to utilize forage almost inaccessible to other species They are agile and sure footed, can graze close to the ground, and are willing to eat almost any kind of vegetation Sheep rank next in these abilities, followed by cattle Sheep and cattle are often handled by the same rancher because the combination makes efficient use of grazing land Cattle prefer to graze tall grass in open areas (Figure 1-5), sheep will consume the short grass and forage on steep slopes

Figure 1 5 A cow herd grazing in the Sand Hills of Nebraska (American Angus Assn)

Though few grazing areas of the United States are so steep and rough that sheep cannot graze, goats are popular in certain mountain areas and in the dry, rocky areas of west central Texas. Because of the adaptability of sheep to higher altitudes than cattle, many flocks are seen in high mountain ranges of Montana, Wyoming, Colorado, and Idaho.

Different breeds, especially among sheep, vary in their foraging ability. The Merino and Rambouillet breeds were developed in rough, hilly country, so are popular in range areas. Mutton type breeds, however, are shorter legged, more compact, and less agile, so are most practical on farms where forage is lush and accessible.

1.9 Degree of Temperature Influence

Extremely hot or cold weather is a stress to any kind of livestock, but the effects are more severe in certain cases. Dairy cattle are extremely sensitive to hot weather; production often goes down markedly during late summer. Production of dairy cattle is enough lower, on the average, in some southern states (Appendix Table 10) that it has been practical to ship milk and milk products under refrigeration from Minnesota, Wisconsin, Iowa, and other northern states. Cold weather is not as great a stress for dairy cattle since they consume large volumes of feed and generate much body heat in the process of utilizing it.

Temperature effects on most breeds of beef cattle are similar. Beef cows consuming large quantities of forage, or fattening cattle on full feed, are not severely affected by cold weather. But since animals of most breeds lose little heat by perspiration, extremely hot weather is a *severe* stress. Cattle of some beef breeds do perspire considerably, however, and because of this and other traits are more adapted to hot climates.

All young and small animals—poultry, calves, lambs, and pigs—are extremely sensitive to cold, damp weather. With a large surface area per unit weight, relatively more body heat is lost by such means as conduction, radiation, and evaporation. Also, in extremely young animals, built-in temperature control mechanisms do not yet operate most effectively.

Among the other temperature influences is the reduction in feed consumption of animals on full feed during periods of extremely hot weather.

Wool on sheep and fat on any animal are good insulators, so help the animal to withstand the cold, but inhibit efficient cooling in hot weather.

1.10 Disease and Parasite Resistance

Young animals are more susceptible to disease and *parasite infestation* than older, more mature animals.

Poultry and swine are most commonly troubled with disease outbreaks. Since they are usually raised in confinement, any organism can multiply and spread rapidly. Also their shorter legs and small bodies may make it

easier for disease organisms on the floor or in feed or water to penetrate the animal body and exert their effect more rapidly than in larger animals

Sheep are very susceptible to parasite infestation and in warm, humid regions must be treated often for parasites during the summer months This is another reason why sheep are more adapted to higher altitudes, where parasites are less numerous

Beef and dairy cattle are troubled much less with disease and parasite infestations than other species This is partially because they are larger, more rugged animals and are often kept on grazing land where disease organisms are not so concentrated More problems are encountered with dairy cows or beef cattle in drylot, and include such things as mastitis, foot rot and shipping fever

1 11 Product

Perishability or stability of product is far less important now than formerly in considering adaptation of species Refrigeration and preservation techniques for milk products meat, and eggs and faster transportation have made this factor less significant.

Wool is a rather stable product, not perishable if stored under good conditions It can be stored many months and can be shipped via relatively inexpensive carriers, so proximity to wool processing plants is not important in considering sheep adaptation

Meat is perishable but not until the animal is slaughtered Animals can be shipped great distances for utilization, and with freezing canning, etc, only *cost* limits the distance the carcasses or meat products can be moved

Fast movement of fluid milk under refrigeration concentrating, condensing and drying milk, canning cream, and other developments have made even the location of dairy farms much less dependent, and almost independent, of the site of consumption

1 12 Labor Requirement

Labor needs of livestock enterprises vary greatly, depending on area of the country, size of operation, capital and equipment available, and managerial skill of the farmer or rancher There are however, some general differences among species and types of operations which can be discussed here Table 1 3 provides a basis for this discussion

The labor requirement for dairy cattle is relatively high because each animal is usually individually fed a concentrate mixture and the cows are milked two or three times per day (Figure 1 6) Milking machines have greatly reduced the labor per cow, but machines still must be attached, watched removed and sterilized for each cow *High quality* labor is important, because of the value of each cow Cows must be milked out completely, injury to or infection in the udder must be noted and treated, and

Table 1-3. Relative Labor Needs of Livestock Enterprises

Enterprise	Labor quality	Labor quantity
Dairy herd	Very high	Very high
Beef cow herd	Average	Average
Sow herd	High	High
Ewe flock	High	Average
Lamb feeding	Very high	Depends on Automation
Cattle feeding	Average	
Hog feeding	Low	
Layers	Average	
Broilers	Average	
Turkey poults	High	

care must be taken to avoid spreading mastitis or other disease from one cow to the next.

The labor needs of a ewe flock are not usually considered high, but since each ewe is less valuable than a beef cow, it may require considerable labor *in relation to* the investment. This can be an advantage to young farmers who are limited in capital but have ample labor. The use of considerable labor in this type of enterprise may mean a high return on capital invested.

In feeding operations involving broilers, turkeys, hogs, cattle, or lambs, labor needs can be greatly reduced by automation. The same is true for laying flocks. Less attention need be given to individual animals, as compared to ewes, dairy cows, beef cows, or sows. If adequate supervision is given, *lower quality* labor can be used.

Figure 1-6. Relatively more and higher quality labor is utilized with a dairy herd. (Babson Bros. Co.)

Though labor might be considered mobile, since people can move to where jobs exist, research has indicated this is not necessarily true. Many rural people refuse to leave their home areas, even if better jobs and higher incomes are promised. They are willing to work for lower wages in order to remain in their native location. This is one reason why contract feeding operations with swine and poultry have flourished in the southern states with feed companies and other groups providing the supervision.

In addition to the total amount and quality of labor for a certain livestock enterprise, *timing* of the labor requirement is also highly important. Where diversified farming is practiced, labor needs of livestock should fit crop needs, dictated largely by season. Hence, winter feeding of cattle and lambs in the Corn Belt not only utilizes locally grown grain, but also surplus winter labor. Similarly, farrowing sows in early spring and early fall makes more efficient use of farm labor.

1.13 Capital Requirements

The capital needed for the establishment of a livestock unit is important, especially to a young farmer. Most beginning farmers or ranchers are short on capital, yet need quick return. Also, they cannot afford great risks.

Because of their prolificness and rapid maturity, hogs are probably most ideal for a young farmer, from the standpoint of capital, in areas where *grains are grown*. Under typical conditions a farmer can buy ten bred gilts, market eighty 200-pound hogs in nine months and have ten gilts left to replace the first ten. With this or a similar system, the *only cash outlay* for breeding stock is the initial herd purchase and the annual purchase of boars. The size of the herd can be increased rapidly.

Figure 1-7. Cattle on feed in Colorado. Such operations require considerable capital, though there is quick turnover. (American Hereford Assn.)

Cattle and lamb feeding, though profitable most years, demands *much* more capital and also involves more risk (Figure 1-7). The same is true for broilers and turkey poults. Though demanding much capital, these enterprises *do* provide relatively quick return.

Because forage is the only feed, ranching in the range areas is obviously restricted to cattle herds and sheep or goat flocks, or "steer" ranching, where calves or yearlings are purchased, wintered, and grown on summer forage before being sold for concentrate feeding or for slaughter. Volume is essential for adequate income so initial capital needs are high.

1.14 Building and Equipment Needs

Because of the need for sanitary handling and quick cooling of milk, and in order to use labor on dairy farms most efficiently, equipment needs on a dairy farm are high. Cost of equipment per cow can be relatively low, however, in large herds where facilities are used efficiently.

Shelter needs of livestock are closely associated with sensitivity to extreme temperatures, discussed in Section 1.9. Baby pigs, lambs, and calves born on cold winter nights need a warm, dry pen. Baby chicks and poults need uniformly warm facilities that are dry and free of drafts. Shelter needs of other livestock are not excessive, however, and good production units can operate profitably without elaborate shelters.

There is no limit to the amount of money that *can* be invested in buildings and equipment. The profitability of any equipment must be determined by the farmer or rancher.

2

THE LIVESTOCK INDUSTRY

This chapter is designed to cover the *breadth* of the livestock industry, including much more than simply production of animals. The livestock producer—grower or feeder—depends on many individuals and groups for "ingredients" for his products (meat, milk, eggs, and wool). He is equally dependent on other individuals and groups for essential services and for processing and merchandising his products.

Markets and meat packers have been a significant part of American agriculture since soon after the Pilgrims landed. Woolen mills and dairies also developed early as specialized businesses. Veterinarians have long been clearly identified because of their need for special academic training. Agricultural colleges, experiment stations, and extension education programs have developed and distributed valuable information to help growers and feeders produce and market more efficiently.

The increasing specialization occurring in this century has rather clearly defined and differentiated several other segments of the livestock industry. The feed manufacturing industry, beginning about 1900 as an outlet for certain packing house and other industrial by products, has grown tremendously because of increased animal nutrition knowledge, specialization of the production units, and confinement rearing of livestock, and because of the development of feed additives that benefit the livestock producer. Pharmaceutical companies and manufacturing chemists, which produce vitamins, antibiotics, amino acids, coccidiostats, and other feed additives may be considered a part of the feed industry (Figure 2-1).

Though livestock equipment has been manufactured for centuries, specialization, the desire to lower labor requirements, and certain refinements in production have stimulated interest and growth in this field.

Identification of livestock breeders as a specific segment of the livestock industry, relatively separate from commercial growers and feeders, is a recent concept. In order to continue to improve livestock in breeding herds by selection, breeders have had to refine selection techniques, requiring more training, effort, and equipment. Earlier livestock improvement was easier because of the great range in quality and the ease of selecting the best. But as poorer strains have been eliminated, the task of identifying the

demonstration farms where their products are tested and new mixtures are tried Some also do basic research in animal nutrition, using laboratory facilities This survey did not include other employees who are technically trained, such as economists and marketing specialists

About 30 per cent of the *concentrates* fed to livestock are mixed and sold by feed manufacturers This does not include the many tons of soybean meal, cottonseed meal, and other single high protein concentrates sold to ranchers and feeders Table 2-1 indicates the proportion of manufactured feeds that are prepared for the different species The highest proportion is fed to poultry, because of their relatively high protein requirement and need for supplemental vitamins, and also because "complete" rations are being used more in poultry feeding A wide variety of products are mixed and sold, especially designed for particular species, certain periods in the animals' life cycle, and specific management conditions

Table 2 1 Proportions of Manufactured Feed in 1961 According to Species*

Species		Percent
Poultry		53
Starter-grower	5	
Layer-breeder	22	
Broiler	20	
Turkey	6	
Dairy		19
Swine		15
Beef and sheep		9
Miscellaneous		4

* American Feed Manufacturers Association Inc

The proportions given in the previous table have been rather stable since 1948, though total tonnage has increased steadily during that time from about 25 to 40 million tons The proportion of feed manufactured for dairy cattle may seem surprisingly high This is partially due to the large dairies, especially on the west coast, where most concentrates are purchased, usually as a complete mixture

The feed industry is highly competitive Over 1100 different companies sell feed in Iowa—mixed supplements, complete rations, oilmeals, and premixes (Figure 2 2) It is not uncommon to have as many as 20 or 30 salesmen and dealers competing in a given area in the Midwest where livestock density is high This intense competition has encouraged many companies to finance feed purchased by farmers, and offer management advice and service A number of companies have contracted with growers and feeders to feed their brand in return for financing management, and marketing help Sometimes even breeding stock is provided at a certain lease price Such arrangements vary greatly and are discussed in more detail in Section 10 8

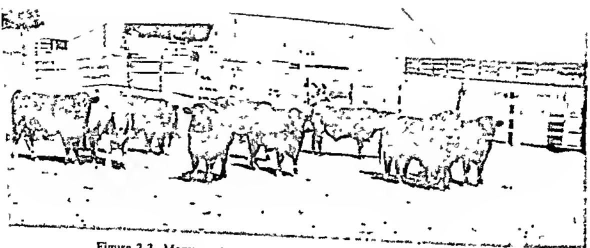


Figure 2-3. Many western ranchers use only bulls from "performance tested" cows. (American Shorthorn Assn.)

Whether he lives on a 160-acre farm in southern Indiana, or on a 10,-000-acre ranch in Montana, the livestock breeder is analogous to the feed industry as a supplier of "ingredients" for the commercial grower, feeder, or dairyman. Livestock breeders supply the "seed stock" for commercial herds and flocks just as hybrid corn companies supply seed for commercial corn growing or breeder hatcheries supply chicks for commercial egg production.

Most breeders raise and sell purebreds—animals that are registered by one of the established breed organizations. Some, however, sell inbreds or hybrids—special strains which have been developed by selecting and/or crossing animals which have desired traits. A few suppliers of breeding stock, especially of bogs, have developed specific inbred lines, each developed for certain recommended mating systems.

Livestock breeders exert great influence on the quality of future livestock. Traits and characteristics passed from one generation to the next by inheritance are considered permanent. They can be eliminated only by selection—culling the animals that carry the traits. Because breeders play such an important role in shaping the livestock industry in terms of livestock quality, they must exert much effort on accurate selection.

Most breeders are extremely loyal to their own breed, though it is apparent that all breeds contain many good animals. Most breeders are active members of their state and national breed associations. Many participate in state, regional, and national shows, competing for prizes, advertising their herds or flocks, and promoting the breed.

Most breed organizations have almost identical goals. Secretaries and fieldmen are employed to promote the breed, handle registration of animals, and help members with production problems, sales, and purchases. The

main function of breed organizations, however, is to improve quality and production traits within the breed. Because of this common purpose the swine breed organizations have formed the National Association of Swine Records to develop uniform standards for all breeds for use in selection and improvement programs.

2.3 Livestock Equipment

Though representing a small proportion of the costs in livestock production, equipment for growing and feeding is currently of great interest. Mechanization in many operations will improve efficiency or increase the size of operation and reduce labor requirements. Developments in nutrition and disease control have made confinement rearing of many animals feasible, changing the equipment needs. Low cost electrical power on most farms and ranches has made possible further mechanization and labor-saving devices. New pieces of handling equipment have been developed. These and other factors have antiquated many farm buildings, making them unsuitable for efficient livestock operations in the last half of the twentieth century.

Figure 2-4. Farrowing crates to save pigs and milking parlors to save labor became popular during the 1950's. Both generally required renovation of old farm buildings or construction of new ones to be fully effective. (Iowa State University and Babson Bros. Co.)

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Figure 2-4. Farrowing crates to save pigs and milking parlors to save labor became popular during the 1950's. Both generally required renovation of old farm buildings or construction of new ones to be fully effective. (Iowa State University and Babson Bros. Co)

Many barns, cribs, hog houses, and sheds have been on farms since the land was first settled, many others were built thirty or more years ago when livestock operations were materially different than they are today. Most midwestern barns, unless recently renovated, have stalls for six or eight horses, stanchions or chains for six to ten cows, several small grain bins, and a hay loft or mow. In contrast, a typical farm today has no work horses and either none or more than 40 dairy cows. Few older barns can be cleaned with tractor mounted scoops or blades.

Present buildings are a real problem on many farms. Not designed or located for efficient operation, some are too good to tear down but do not justify major remodelling expense. If retained they are taxable and must be kept in repair, representing an expense.

Some buildings on farms are more elaborate than practical. A few have been built to satisfy pride. Many are designed to keep the farmer comfortable, though the livestock need only a simple shelter. Few provide adequate ventilation, large open doors and unobstructed areas for mechanical cleaning, sloping concrete floors for good drainage, or gravity feed movement. Others are dilapidated. These, however, present little problem because the obvious solution is to eliminate them and replace them with a modern, simple, usable structure.

The situation described, coupled with new knowledge on shelter needs of animals, indicates the opportunity for those interested in livestock housing. Many new and different buildings have been designed and built, others are being planned. It is suggested that new buildings be designed for versatility and changes in production systems which we know are inevitable.

Some buildings must be fairly elaborate (Figure 2.4). Housing for sows and baby pigs must be insulated for both winter cold and summer heat. Heating and air conditioning are often practical, and other expensive equipment is often needed.

Development of large commercial feed lots—specialization—has made mechanical feeding practical. Power-operated mixing and unloading wagons and trucks, which distribute concentrates or complete rations into bunks, are in common use. Self feeders are used for cattle and sheep as well as for hogs. Some feeders have installed permanent feeding systems, using augers, drags, or other devices to distribute feed to cattle, lambs, and hogs. Some are equipped with timing devices so that feeding is completely automatic. Grinding, mixing, and pelleting equipment for medium and large sized feeding operations are available.

Automatic waterers attached to a pressure system and heated by electricity, gas, or oil are common. In some cases water is kept from freezing by continuous circulation, spending part of the time in the system below frost line. Pressure systems and automatic heating make it unnecessary to build large concrete, wood, or steel tanks for a few animals.

Power cleaning equipment—tractor mounted scrapers and scoops for

large sheds and feeding floors, and various gutter cleaners for dairy barns —and pressure water systems have taken much of the labor out of cleaning facilities and handling manure. Concrete lots and sloping feeding floors have made the job easier and often pay for themselves with improved feed lot performance. Much manure is now handled in liquid form, loaded by pumps or by gravity, or is permitted to decompose in lagoons.

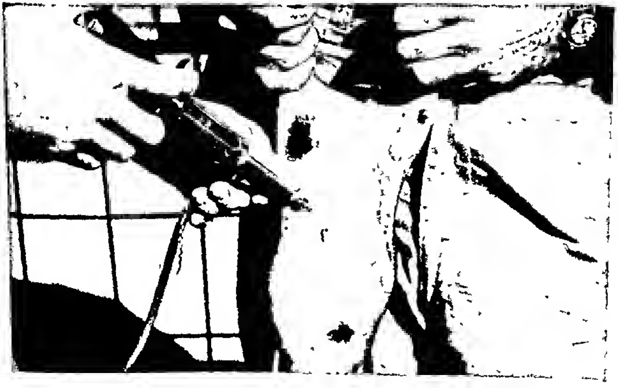
Handling equipment such as portable squeeze chutes, scales, and calf tables are manufactured by a number of companies.

Who designs, builds, and sells these buildings and this equipment of the present and the future? People who know livestock and its needs, who have imagination and mechanical skill. They are a significant part of the livestock industry.

2.4 Veterinarians

About 10,000 practicing veterinarians, according to the American Veterinary Medical Association, help maintain the health of livestock on farms and ranches in the United States (Figure 2-5). Others employed by government regulatory and research organizations are concerned with protecting human health. Many serve as inspectors, checking processing plants for sanitation and poultry or animals for indications of infectious disease. Veterinarians in industry or on experiment station staffs are involved in research work in animal diseases and their prevention. Others operate smal animal clinics for pets.

Figure 2-5. *Disease prevention by immunization is a major task of the veterinarian.* (Iowa State University)



Though some of the older veterinarians were trained in private veterinary schools in operation during the nineteenth and early part of the twentieth century, most present veterinarians are graduates of one of the 20 publicly supported veterinary colleges in the United States and Canada

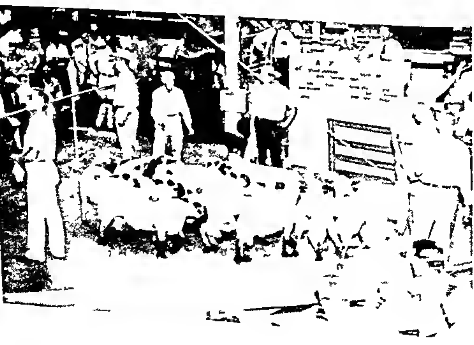
2 5 Livestock Markets

The livestock industry embraces the 65 or more terminal livestock markets including Omaha, Denver, Cincinnati, and Houston, as well as hundreds of livestock auctions dealers and traders Marketing naturally involves truckers railroads, transit insurance companies, banks, market news services and other agencies Though a detailed discussion of markets and how they operate is provided in Chapter 20, the general role they play in the livestock industry should be emphasized here

Markets are the common link between producer and processor (though many producers sell directly to processors) and are an often used link between two producers For example, ranchers may sell feeder lambs and cattle to livestock feeders through dealers, auctions, or terminal markets Many feeder pigs are handled by dealers and a large number are also sold through auctions Some animals pass through several markets between birth and eventual slaughter

Prices are generally established at the markets, so they can be considered the "barometer" of the livestock business Supply and demand are balanced and a price, dependent on weight, grade and quality, results (Figure 2-6)

Figure 2-6 Breeding rams at a livestock auction in California (American Hampshire Sheep Assn)



Since animals at most markets are appraised visually by both buyer and seller, or their agents, market men must have a "trained and experienced eye." They must be able to estimate weight, quality, and, in the case of slaughter animals, dressing percentage. Profit or loss, for the buyer or seller, often depends on the accuracy of one man's judgment.

2.6 Meat Processors

Finished cattle, hogs, and sheep go in one side of a packing plant—beef loins, hams, sliced bacon, legs of lamb, weiners, sausages, lard, and hundreds of other meat products come out the other. A packer is really a "disassembler" of meat animals. But he also prepares some of the disassembled cuts so they are ready for cooking, or in some cases, ready to serve. Chapter 24 is entirely devoted to meat processing.

The word "packer" was first used to describe a meat processor in the late 1700's, when most meat was packed in salt, in barrels, for preservation. Mechanical refrigeration was not available and packing in salt was the best preservation technique known for storage and shipping.

Currently there are over 3000 slaughtering establishments that each handle over 300,000 pounds of live animals annually. There are also several thousand smaller plants (Figure 2-7).

Most large packers turn out a wide variety of meat items. Most good quality lamb and beef leaves the plant as carcasses, halves, or quarters; nearly all pork carcasses are broken into cuts. Pork loins and shoulders may be distributed fresh, but hams and bellies are usually cured and smoked. The bacon (cured and smoked belly) is sliced and packaged. Lower quality carcasses of all species are often "boned out" in the plant. The lean and fat are ground and made into weiners, sausage, chili, or other "prepared" meat items.

The amount of processing—preparing meats for cooking or for the table—is increasing in most plants. Most packers prepare oven-ready or pan-ready cuts—packaged, weighed, and identified by brand name—which are displayed by retailers in self-service coolers. Several packers sell frozen, boneless steaks, roasts, etc., in family-sized units so the housewife doesn't even have to carve around the bone.

Such services cost money, but as the level of living has risen and as an increasing number of housewives work outside the home, consumers are willing to pay for, and even demand, such services. This means that the meat processing industry not only slaughters, chills, and distributes beef, pork, and lamb, but is a complex industry preparing and delivering meat items the consumer desires.

Efficient meat processors have buyers who can accurately appraise animals, production managers who can direct crews of men, meat specialists who know meat and meat-product preservation and quality, salesmen who are sensitive to consumer desires, and other important, highly trained people.

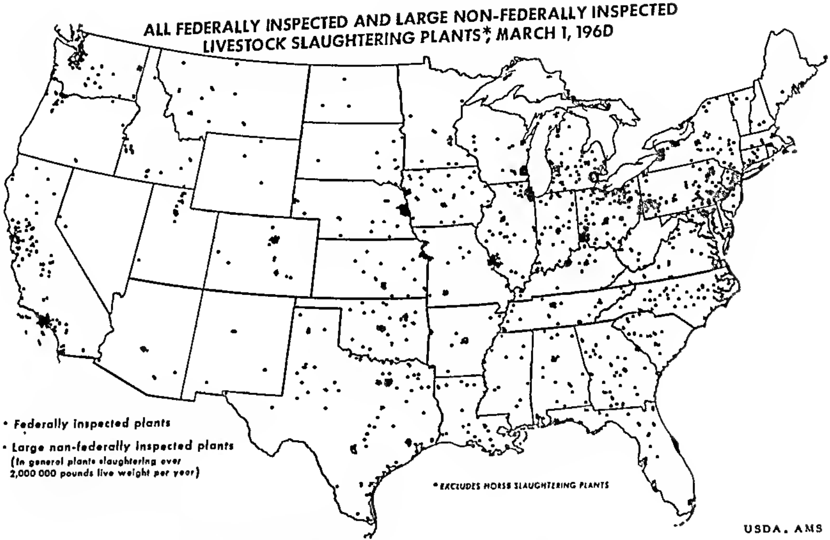


Figure 2-7. Distribution of large livestock slaughtering plants in 1960.

2.7 Wool Markets and Mills

This topic—the movement and conversion of a freshly clipped fleece into a woolen sweater or worsted suit—is analogous to the previous discussions on livestock markets and meat processors.

Because not as much wool as meat is produced in this country, and because wool is not a highly perishable product, there are fewer wool markets. Most producers are a considerable distance from a market.

Boston, considered the center of the wool market in the United States, is where most buyers and sellers meet. Buyers represent specific mills or groups of mills. A seller may represent an independent trader who has purchased wool from many producers, but more often represents a wool marketing cooperative, formed by a number of wool producers in the same area. These wool marketing cooperatives, or "pools," are numerous. Because they are large and represent many growers, they have considerable bargaining power at the market.

According to the 1958 Census of Manufactures, over 600 woolen and worsted manufacturers in the United States produced and distributed over a billion dollars worth of woolen cloth and fabric. Over half of the mills are located in the New England states, having developed there in the early settlement days. Though this area provides ample water power, labor costs have risen and some mills have moved to southern states.

Much of the wool used in the United States mills is imported, primarily because of lower prices (even after import duties are paid).

The fascinating story of the wool fiber and how it is made into cloth, as well as a comprehensive discussion of wool marketing, is presented in Chapter 27.

2.8 Dairy Plants

Because milk is a perishable product most small towns and villages have long had dairy plants to separate, pasteurize, and bottle milk for consumers and to make butter, cheese, ice cream, and other dairy products. But as the perishability of milk and milk products has been conquered by refrigeration, drying, condensing, canning, and other techniques, and as packaging materials and transportation have improved, the dairy processing plants have centralized considerably. Former plants in many small towns are closed. Fresh milk is often hauled many miles in refrigerated trucks for processing. Products are then redistributed over a wide radius. Between 1940 and 1960 the number of plants handling dairy products dropped sharply, though total production increased materially.

Most plants are privately owned, many by large corporations who operate several plants. Others are operated as producer cooperatives, usually handling milk from a wide area.

Since milk is still a potentially perishable product, most cities enforce rigid sanitation ordinances pertaining to milking facilities, transportation, processing, and storage

2.9 Government and Educational Agencies

Various governments, especially the federal government, spend considerable money annually in (1) interpreting and enforcing *laws and regulations* concerning imports and exports, animal health, and processing of animals and animal products, (2) *grading* livestock products into quality groups, (3) supporting *research* in animal production, marketing, and preservation, and (4) *educating* students, farmers, consumers, and others in schools, universities, and extension programs

Most federal regulations concerning animals and animal products are executed by the USDA, whose secretary is a member of the President's cabinet Different segments of this department assume specific functions For example, the Meat Inspection Division of the Agricultural Research Service culls diseased animals brought to slaughter, provides for post mortem examination of slaughtered animals and parts by veterinarians, and enforces sanitation requirements in slaughtering establishments (Figure 2 8) All meat shipped in interstate commerce bears a stamp "U S Inspected and Passed"

Figure 2 8 Federal inspectors check carcasses and internal organs on a pork processing line (Swift & Co)

States also act to regulate marketing and processing, as well as product quality. A number of states provide for classifying and pooling fluid milk for use in metropolitan areas and specify the minimum price which dealers must pay producers, this regulation enacted "for the purpose of regulating and stabilizing the milk industry." Most states have enacted and enforce feed laws, which generally require that commercial feeds be properly labeled and contain ingredients and nutrients indicated on the label. Meat processors not covered by the federal laws, because they do not ship meat interstate, are usually affected by similar state statutes.

Because much of the milk consumed in the first half of the twentieth century was produced on nearby farms and processed in local plants, cities early assumed the responsibility for insuring clean, wholesome milk by enacting special ordinances. Many cities also regularly inspect small slaughtering plants, food wholesalers, retailers, and restaurants.

As a guide to the consumer the USDA has developed grades for many animals and animal products, as well as for other agricultural commodities, and employ specialists to do the grading. Whereas most inspection and regulation is done at government expense to *insure* that it be done, most grading of products is considered a nonessential service that must be paid for by the subscriber. A packer who wants his meat carcasses identified according to USDA grades pays the USDA for this service.

The Morrill Land-Grant College Act of 1862 provided support for colleges in each state to teach developments and knowledge in livestock production and in other phases of agriculture. These colleges expanded in size, course offerings, and curricula to include many fields other than agriculture; many are now universities. Though most students of Animal Science complete only a four-year program, some continue in advanced study to earn the Master of Science or Doctor of Philosophy Degree. Some state-supported schools, other than land-grant colleges, also teach courses pertaining to the animal industry, as do many private institutions.

Land-grant colleges and universities usually have intensive research programs in nutrition, breeding, marketing, reproduction, meats, and other fields, organized in an Agricultural Experiment Station and financed by federal and state funds as well as private grants. The Agricultural Extension Service, an integral part of the Agricultural College at most Land-Grant Universities, is responsible for educational programs involving farmers, ranchers, others with agricultural interests, and consumers. Subject matter specialists aid the county agent, farm adviser, or extension director and other extension staff located in each county (Figure 2-9).

Privately endowed research organizations benefit the livestock and related industries. Trade groups, representing various segments of the industry, not only promote their products to encourage increased consumption, but also support research and educational programs in public and private institutions for the entire livestock industry. Among these are live-

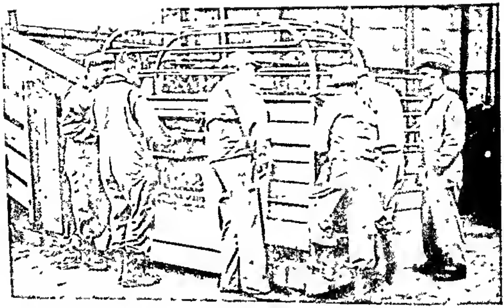


Figure 2-9. Livestock extension specialists, left foreground, work with livestock growers associations in getting "performance testing" programs started. (Iowa State University)

stock breed associations and the American Feed Manufacturers Association, both discussed earlier in the chapter. The American Dairy Association and the National Livestock and Meat Board carry on extensive educational programs concerning the value of milk and meat in the diet. The American Meat Institute, an organization of packers and related companies, supports extensive meats research in a special foundation located on the University of Chicago campus. There are many national, state, and local producer groups, such as the American National Cattlemen's Association, the National Wool Grower's Association, and the National Swine Grower's Council. Activities of such organizations are commonly financed by grants from industry members, membership fees, and small contributions from buyer and seller at the market.

2.10 Horses and Ponies

On January 1, 1962, there were an estimated three million horses and mules on farms. Though many are used for fence riding in range areas, as well as sorting and herding cattle and sheep, a large number are owned primarily for pleasure. This estimate does not include many light horses kept in non-farm stables and used for pleasure. With a higher level of living, shorter work weeks, and an increase in the percentage of urban dwellers, horseback riding has increased greatly in popularity. Horse racing continues to be a popular spectator sport, though it is a highly specialized business and involves relatively few animals.

Great interest has developed in ponies in recent years. Though no accurate figures are available, it is apparent that numbers have increased markedly.

3

LIVESTOCK SCIENCE

Livestock production on farms and ranches today is not considered a craft or an art by successful producers. It is a competitive business where management decisions are based on scientific principles. The same is true in the feed industry where electronic calculators and automatic blending equipment are replacing the pencil and scoop shovel. In the meat industry assembly-line smoking of bacon with electrically charged smoke particles is being tried. Meat is preserved by refrigeration, irradiation, and antibiotics, rather than in salt barrels. Similar developments in all phases of the animal industry have put the spotlight on science.

Just as Chapter 2 presented a panoramic view, showing the breadth of the animal industry, this chapter is devoted to illustrating the depth of livestock science. Farm and ranch management practices, nutrient levels of rations, mating programs followed by a livestock breeder, ham curing techniques in a packing plant, assay procedures used by a state feed chemist, and other such "routine" procedures, are based on a number of scientific disciplines. Genetics, chemistry, mathematics, physics, economics, physiology, bacteriology, and other "pure" sciences are the foundation of livestock science.

Scientific journals, such as *Journal of Dairy Science, Journal of Nutrition, Poultry Science,* and *Journal of Animal Science*, serve as official records of new information (Figure 3-1). Research conducted at state agricultural experiment stations, as well as other public and private research institutions, is summarized and printed in these volumes. Such research is the basis of many common practices and procedures on farms and ranches or in processing industries. Research reports also guide other research workers in the quest for new knowledge in animal science. Research may also be summarized in experiment station bulletins.

Men who work with livestock are becoming more objective. Though most continue to have an intense feeling for livestock and the livestock industry, the desire for profit clearly exists. Farm animals are meat, wool, and milk producing factories. Profit-minded growers and feeders must know their factory—what it consists of, how it works, what factors influence it, what can make it run efficiently—and they must be conscious of product quality.

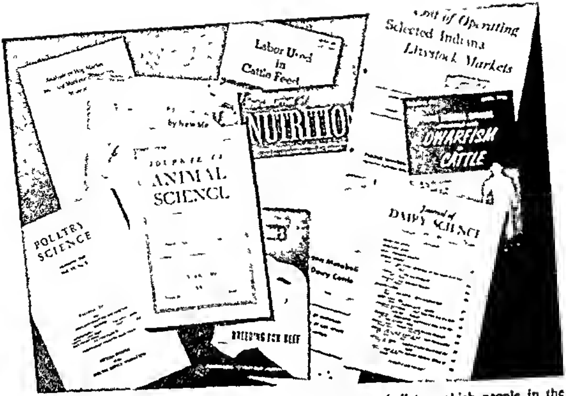


Figure 3-1. Research journals and experiment station bulletins which people in the livestock sciences follow carefully to keep abreast of new developments in production, marketing and processing. (Iowa State University)

3.1 Heredity and Environment

One of the first concepts that must be established in studying livestock is the relationship between heredity and environment. Any animal, at any time, is a product of its heredity and the environment to which it has been exposed.

Heredity includes those traits or factors which are transmitted from one generation to another by the reproductive cells of the parents, the sperm and the ovum. Environment includes the many additional factors which might influence an animal's performance after its heredity has been established, such as ration, disease, climate, housing, water supply, mechanical injury, and other aspects of management.

It is important to realize when during the life cycle of an individual heredity and environment exert their influences. This is illustrated in Figure 3-2. It can be seen that the heredity of an individual is determined at conception when the sperm—the reproductive cell from the male parent—and the ovum—the reproductive cell from the female parent—unite to form a zygote. The details of this fertilization and the mechanics of heredity are discussed in detail in Chapters 13 and 14.

Any influence which is exerted upon the individual following *conception* is considered environmental. This includes the time that the developing embryo is contained inside the uterus of the dam. For example, nutritional deficiencies the dam may incur during pregnancy can seriously impair the

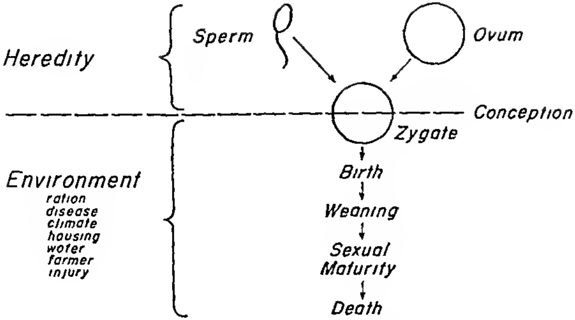


Figure 3-2 The heredity or genetic make up of an individual is determined at conception, when the sperm and ovum unite to form a zygote Anything which later influences or affects the individual is considered environmental

development and later health of the offspring One specific example is vitamin A During the drier years, especially in the southwestern part of the United States, many cows receive very little vitamin A during pregnancy Calves are often weak at birth, some are blind or have weak eyes Therefore, such a defect at birth may have an environmental cause

The presence or absence of many diseases will influence whether or not the embryo lives long enough to be born Leptospirosis and brucellosis can exert a direct effect upon the embryo and can kill it before birth In such a case the death of the embryo is caused by environmental factors (disease), not by heredity

It should be emphasized that the genetic make-up (heredity) of an individual does not change after it is once established [1] Environmental factors which might influence performance or visual characteristics of an individual do not change the genetic make-up For example, a cow with a "blind" quarter (one teat not functional) because of injury or mastitis infection will not genetically transmit this trait to her calves A sow stunted in size because of an inadequate ration will not genetically transmit this characteristic to her offspring Nor will a ram with a broken horn sire lambs with the same trait

3.2 Nutrition

Animal nutrition knowledge has developed rapidly during the last half century It has been the most studied of the environmental factors influenc-

[1] Rare changes in genetic make up are caused by mutation but these are not of common occurrence and will not be discussed in this text

ing animal performance Though the need for carbohydrates, proteins, and fats in animal diets was recognized early in the nineteenth century, it was not until about 1910 that Babcock, a chemist at the Wisconsin Experiment Station, and his associates demonstrated that other "factors" were also needed In their studies rations composed entirely of wheat (plus salt), containing ample carbohydrate, fat, and protein, failed to support normal growth, reproduction, and lactation in heifers Heifers receiving only corn (and salt), however, grew well, each produced a normal calf, and they produced three times as much milk the first month after calving as the wheat group We now know that vitamin A activity in corn, but not in wheat, was the main cause of the contrasting performance

Since most vitamins are rather unstable, complex, and present in minute amounts, identification of them is a difficult task Vitamin A was identified only after successive demonstrations indicated the presence of a beneficial factor in milk fat, vegetable foods, and cod liver oil, as well as in corn Chemical procedures disclosed the factor was in the fat-soluble portion of the feeds, and in plants it was associated with yellow pigments Other potent sources of the factor, however, were colorless Today we know the yellow pigment, carotene, is contained in plant materials but is largely converted to vitamin A when the plant feeds are consumed The relationship of the yellow carotene and colorless vitamin A was established *only* by appraising and comparing the *chemical* and *physical* properties of the purified compounds Today, vitamin A potency of livestock feeds is measured by chemical procedures, measuring the density of a brilliant blue color produced when a certain chemical is added to an extracted solution of the vitamin

Other vitamins, amino acids, and minerals have been identified and characterized by similar chemical and physical procedures, such as determining molecular weight, reactivity with known compounds, color reactions, and transmission of light Once the chemical composition and structure of a complex nutrient is established, the manufacturing chemist tries to reproduce it An architect with atoms, he knows how to build certain key parts, and is often successful in duplicating the natural functions of plants and in developing commercial procedures for chemically manufacturing the pure nutrients In the case of some complex nutrients, however, chemical synthesis procedures have not yet been developed

Chemical and physical properties of nutrients, mentioned above, are the bases for many nutrient assay techniques used by nutritionists, quality control chemists for feed manufacturers, and state feed control chemists

Since nutrient utilization in all species is influenced by bacteria and other microorganisms in the digestive tract, nutritionists have directed much attention toward the characteristics, environmental needs, and physiology of such microorganisms In some cases, for example, the rumen of a steer is tapped from the outside and a mass of contents (containing water, feed,

Figure 3-3. Rumen contents are removed, then centrifuged, and the liquid is placed in the artificial rumen, on the right Note the special equipment, needed to simulate rumen conditions (Chas Pfizer & Co. and Iowa State University)

and microorganisms) is removed for study in an "artificial rumen" (Figure 3-3).

When the steer was young the skin and the wall of the rumen (just under the skin) were cut and sewn together, as a buttonhole is made in a double thickness of cloth. The opening is kept tightly closed by a plug, perhaps screwed into a pliable fitted casing.

The artificial rumen consists of a number of small test tubes. Each tube is filled with strained rumen contents, including microorganisms. They are kept in a warm water bath and carbon dioxide is bubbled through, to simulate normal temperature and body movement of the animal. Nutrients or other compounds can be added to the various tubes, and the effect on the microorganisms can be measured. Knowledge gained here may later be applied to cattle feeding. Rations fortified with certain nutrients or feed additives may promote bacterial utilization of roughages.

Physiology—the study of the normal functioning of animal tissues and organs—is important to the nutritionist. Most nutrients actually do their job within tissues, so proper functioning of certain tissues and organs often serves as a measure of nutritional adequacy.

Speedy formulation of nutritionally adequate rations and supplements can be accomplished by an electronic computer, utilizing certain principles of mathematics and physics. Information on nutrient requirements, ingredient analyses, and ingredient cost is fed into the machine via special punch cards and the formula which best meets the requirements is calculated almost instantaneously. Statistics, a branch of applied mathematics, allows safe and reliable interpretation of nutritional research results

3 3 Shelter and Facilities

How much shelter does an animal need for top performance in the winter? Can air conditioning in the summer be practical? Is there a difference in the effects of different building materials? Will cement feeding floors pay? These and other questions concerning shelter and facilities are currently being investigated

Though most livestock shelters now on farms and ranches were built to protect livestock from the heat and the cold so *apparent* to the farmer and rancher current interest is directed to the exact amount and kind of shelter *needed* by the animal for top performance Basic research in fully insulated chambers at the Pennsylvania Missouri and California Experiment Stations has measured the effects of various controlled temperatures and humidity on milk production in dairy cattle and growth in meat animals With such data the practicability of providing shelter and artificial heat and cooling to counteract climatic conditions can be determined

A number of southern experiment stations have measured the benefits of shade sprinklers evaporative water coolers or refrigerated air conditioners on milk production feed consumption gains on pasture and in feed lot ram fertility or survival rate in litters of pigs A series of buildings constructed of steel wood or aluminum have provided information on pig performance at the Iowa Experiment Station A part of this problem is the characteristics of the building material in reflecting or absorbing radiant heat from the sun and *from the animals* inside a building or under a shade Basic animal physiology studies will tell what proportion of the heat emitted by animals is in the form of radiant energy

3 4 Disease Control

Effective control of animal disease involves (1) recognition of the causative agent (2) learning the growth habits and physiology of the bacterium virus or other organism involved and (3) developing chemicals serum and/or sanitation and management practices which will effectively prevent or cure the disease

Bacteriologists and virologists (those who study bacteria and viruses) classify organisms according to their growth habits the kind of nutritional growth media they thrive on and their appearance Continued dilution of solutions known to contain disease-causing agents and checking characteristics of organisms separated in this fashion allows the identification of causative agents In this manner organisms that may be the cause of some new disorder are isolated and characterized

Chemicals manufactured or produced by other living organisms and known to have certain inhibitory properties are then tested both in the laboratory and in animals for effectiveness against the disease producing

organism. Often new chemicals must be developed for specific diseases. A special serum, usually produced by animals infected with low levels of the disease, may be developed.

Dosages must be worked out for various ages and weights of animals, and the effect of these disease-combatting chemicals and serums on other aspects of animal physiology and performance must be checked.

Many diseases and "low level" infections are passed from one generation to the next in livestock herds and flocks by physical contact. This can be prevented by taking developed embryo pigs (or calves or lambs) by surgery before natural parturition. They are removed from the uterus into sterile bags, then taken to new or sterilized facilities and are raised in a relatively disease-free environment. (Pigs handled this way are often called "SPF"—specific pathogen free.) Growth and feed efficiency in such animals often markedly surpasses that of the previous generation.

In some cases, effective disease control is related to breeding programs. Resistance to certain diseases can be inherited. Adequate nutrition is also involved in resisting diseases and infections. Animals are found more subject to certain diseases during and following exposure to severe stress conditions, such as cold, rainy weather, or long-distance shipping.

3.5 Physiology of Reproduction

Though a cow usually gives birth to one calf per year and a ewe normally produces only a single lamb or twins, a sow farrows twice each year with eight or more pigs in each litter. Why? And why do many ewes come "in heat" for breeding only after the cool nights of the fall begin?

Much research is currently being done in the physiology of reproduction to increase the number of offspring per good breeding animal, to better control the time when calves, lambs, and pigs are born, and to improve survival rate during embryonic development. Artificial insemination has been practiced for centuries, but only recently has it been possible to dilute, store, and ship semen so that thousands of offspring can be sired annually by a single high quality sire. Scientists had to learn how many sperm were contained in a given quantity of semen, the amount of energy and nutrients they needed for survival, and how their metabolism could be slowed down so they could be shipped to distant points and remain capable of fertilization. Use of artificial insemination allows faster genetic improvement of animals because only the *best* sires need be used.

There are corresponding attempts to make more efficient use of top quality cows, ewes, and sows. Hormones have been found which cause massive production of ova, the female reproductive cells. After insemination the fertilized ova may be flushed from the reproductive tract and placed in the reproductive tract of "host" cows for embryonic development. This practice has been successful in a few cases but the results are not consistent enough to suggest commercial use of these hormones.

Figure 3-4. Counting live embryos from a gilt slaughtered during pregnancy. (Iowa State University)

Much is also being learned about the effects of heredity, nutrition, and management practices on conception rate and embryonic development. This involves slaughtering animals in various stages of the reproductive cycle so that the number and size of developing embryos and various parts of the reproductive organs can be closely checked (Figure 3-4).

3.6 Genetics

Certain characteristics are passed from one generation to the next by genes carried in the reproductive cells—the sperm and the ova. Color markings of livestock, presence or absence of horns in cattle and sheep, and number of teats on hogs are determined by genes transmitted from the sire and dam All productive traits, such as growth rate and carcass composition, are *partially* determined by genes, though environment exerts considerable influence.

The best breeding systems for continued livestock improvement depend on the extent to which genes influence the important traits, the natural reproductive rate of each species, the age at which the important traits are expressed, and the possibility of measuring the traits directly on the animals intended for the breeding herd. The extent to which genes influence

important traits can be estimated by making large numbers of test matings, examining the resemblance between relatives, and employing certain statistical formulas and techniques.

Livestock breeders also want to know the tendency of certain kinds of genes to mutate or change, the proportion of such mutations which are desirable, and the types of things that will cause mutations. Mice, guinea pigs, flies, and other highly prolific species are used for speed and economy in such research. Results obtained are interpreted by trained scientists for application to farm livestock.

3.7 Selection of Breeding Animals

Controlled studies have indicated a surprising *lack* of correlation between conformation of livestock and certain important characteristics, such as milk production, rate of gain, and feed efficiency. This knowledge has encouraged livestock breeders and growers to search for more accurate devices than the human eye for appraising livestock—whether for culling, for selecting replacement females, or for purchasing sires.

A pencil and a scale are the simplest and most often used tools for rating animals and their offspring. The pencil records such information as dates of breeding and parturition and number of offspring; the scale measures milk production, growth rate, and feed consumption.

Some other characteristics are not so simply measured. Fatness in a potential breeding animal can't be weighed or counted, so other tools for measuring it have been developed. Since the fat layer on the back of a hog contains few capillaries and nerves, a small ruler can be used to measure the fat thickness without harming the pig. Chemical analyses of carcasses have indicated fat thickness is *highly correlated* with the total percentage of fat in the animal. A more complex device (leanmeter) based on the different electrical conductivity of fat and lean is also used. A flaw detector,

Figure 3-5. Sound waves are emitted from the tube held against the pig's back. The time it takes for them to bounce back from tissue junctions is indicated on the screen at right (Iowa State University)

used to measure fatness in cattle or hogs, emits sound waves and records the time it takes for them to bounce back from a junction between tissues (Figure 3 5)

The conditions under which animals will be kept may influence the type of animal which should be selected for certain farms and ranches, there may be a hereditary environmental interaction in some traits Identical twins, which carry identical genes, can provide information on this topic if each member of the pair is subjected to a different environment and performance is measured As in other research the applied mathematical science of statistics helps interpret and measure the reliability of such information

3 8 Merchandising

Economics—the field of supply and demand and the factors affecting each—must be fully understood for effective merchandising of meat, milk, and wool To predict product supplies certain measurable factors such as feed supplies, calf numbers, pig farrowings, and government support programs are examined as they relate to production Effects on consumer demand such as birth rate, movements in population, and income are also correlated Since price is a function of supply and demand, such information is valuable to the producer in making his production plans regarding time, amount, and quality to market Processors, wholesalers, and retailers also use this information to anticipate heavy or light production and to plan sales campaigns accordingly

Marketing specialists also try to measure *elasticity* of demand for competitive products Relatively inelastic demand for a product means that consumers tend to buy regular quantities of the product whether the price remains stable, increases, or decreases If demand is highly elastic, con sumption depends heavily on price and financial condition of purchasers

Surveying consumer desires is an increasingly important part of merchandising animal products As the American level of living has risen and a wider variety of products have become available, consumers have become more particular To effectively compete with other products, meat, milk, and wool must be in the form consumers want Depth interviews conducted by trained sociologists uncover human moods and desires and ascertain whether new food products packaging, or labels might be accepted or rejected by the housewife

3 9 Product Quality

Appraisal of quality in a product as complex as meat or milk is a difficult task Wool can be rather objectively evaluated by measurements of diameter, length, strength, dyeing properties, etc But meat, sold to supply both nutrients and satisfaction through its flavor, aroma, tenderness, juici-

ness, and other such factors, is not easily appraised. The same is true for milk.

Consumers differ in their tastes and desires. Some prefer lamb with a mild flavor; others like a more distinct flavor. Most people prefer meat with considerable fat intermixed with the lean; some prefer as little fat as possible. Milk with a more golden color is consistently purchased for some households; in others, pure white is considered more desirable.

Coupled with the lack of uniformity in consumer desire is the fact that there are few techniques or devices to *quantitatively* measure quality factors in meat or milk—flavor, palatability, and aroma—plus the tenderness and juiciness of meat. A shearing device is a fairly reliable indicator of tenderness; fluid forced out of meat under pressure is an index of juiciness. There are recently developed chemical procedures for measuring "connective tissue" in meat and this may help measure tenderness. But much reliance for measuring quality in meat and milk must still be placed on panels of trained people who can repeatedly discriminate among various flavors and other food characteristics (Figure 3-6).

Though more accurate and reliable methods of appraising quality of animal products are still being developed, the techniques mentioned above are now being used extensively in appraising effects of nutrition, management, and inheritance on product quality. Just as breeders are searching for better indicators of productive merit in breeding animals, so are processors hunting for better indicators of product quality in cattle, lambs, and hogs for slaughter. Processing, storage, and handling procedures, and *their* effect on product quality are also being appraised.

Figure 3-6. A trained panel scores samples of beef subjected to various tenderization treatments. (Am. Meat Inst Found.)

3.10 Product Preservation

Until development of mechanical refrigeration, most perishable food products were preserved by drying, salting, or canning—effective methods employing sound principles Most spoilage of foods, other than the oxidative changes in flavor and color, is caused by certain microorganisms which need water, air, and nutrients for survival and reproduction Some are also extremely sensitive to concentrations of salt and other minerals Drying of food eliminates the water Salt has much the same effect, removing water from tissue cells by osmosis, and may also directly inhibit the organisms Canning cuts off the oxygen supply which most bacteria need and the supply of carbon dioxide needed by yeasts, some of which can also cause spoilage

Cooling or freezing is effective in preservation of meat, dairy products, and other foods because most bacteria are either killed or severely inhibited, depending on the temperature Refrigeration also slows down certain chemical changes which might occur in milk or meat Radiation is currently being used, at least experimentally, in meat preservation Since the meat is completely sterilized, it may be stored for a considerable time at room temperature without bacterial spoilage Meat and dressed poultry are sometimes dipped in solutions of antibiotics to increase the time they can be kept in refrigerated display coolers or home refrigerators

Though the techniques mentioned above are all effective in preventing

Figure 3-7. A meat chemist uses a chromatographic column to separate myoglobin the meat coloring pigment, from beef tissue Intense study of myoglobin may provide clues to retaining natural beef color during storage (Am Meat Inst Found)

bacterial spoilage, each has certain effects on the flavor, color (Figure 3-7), and desirability of the product. Salt tends to promote oxidative rancidity in cured pork, especially if poorly wrapped. Meat preserved by exposure to radiation loses much of its flavor and color, so is less appealing to consumers. If meat is frozen too slowly, it loses much of its juices during thawing and cooking because ice crystals that form slowly rupture tissue cells.

The above illustrates that effective and satisfactory preservation of animal products involves detailed knowledge of the products, the effect of preservatives on organisms, and also the effect of preservatives on other characteristics of the preserved product.

4

NUTRIENTS

A nutrient is a food constituent that aids in the support of life It may be a single element such as iron or copper, or it may be a large complex chemical compound such as starch or protein, composed of many different units

About 100 different nutrients are known to have value in livestock rations Many are individually required for normal body metabolism, growth, and reproduction, the others are either not essential or can be replaced by other nutrients

Good nutrition in farm animals is greatly dependent on agronomic science since plants and plant products are the ultimate source of most nutrients in livestock rations Some rations contain animal by product feeds, but nutrients in these feeds had their origin in plants

4 1 Nutrient Formation

Nutrients that are a single element are absorbed from the soil by the many fine, penetrating plant roots These elements may be in free form in the soil or they may be contained in simple compounds Absorption by plants is described in Figure 4-1

Carbohydrates, fats, and proteins, which are rather complex nutrients, are manufactured by photosynthesis and other chemical processes in plant tissues Catalyzed[1] by chlorophyl present in green plant cells, photosynthesis combines carbon, hydrogen, and oxygen from the soil, air, and water into carbohydrate molecules Energy, provided by the rays of the sun, is captured in these molecules The net process of photosynthesis is usually described as follows

$$6\ CO_2 + 6\ H_2O + \underset{(673\ \text{Calories})}{\text{Radiant Energy}} \xrightarrow[\text{Chlorophyl}]{\boxed{\text{Photosynthesis}}} C_6H_{12}O_6 + 6\ O_2$$

[1] Catalyst—an element compound or other factor which speeds up a chemical reaction the catalyst being unchanged at the end of the reaction A catalyst does not initiate a reaction but merely alters the speed In this case the chlorophyl molecules catalyze the photosynthetic process. The exact mechanism is not known

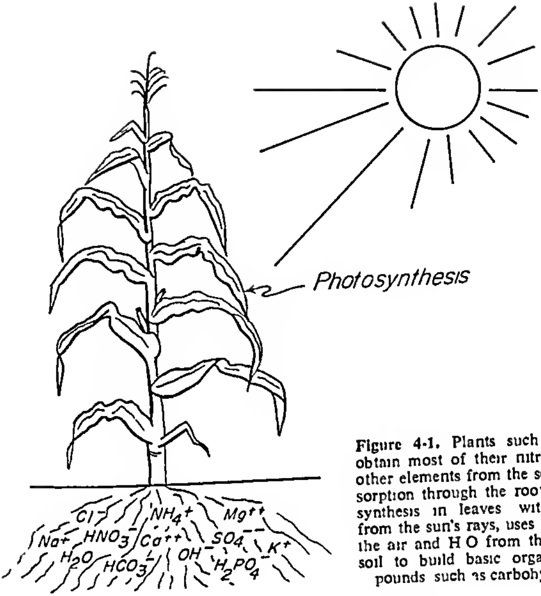


Figure 4-1. Plants such as corn obtain most of their nitrogen and other elements from the soil by absorption through the roots. Photosynthesis in leaves, with energy from the sun's rays, uses CO_2 from the air and H_2O from the air and soil to build basic organic compounds such as carbohydrates.

Carbohydrates, the main form of energy storage in plants, form most of the plant structure. A large part of the plant fat (formed from carbohydrates after photosynthesis) accumulates in the seeds, supplying a concentrated source of energy for germination and early growth in the new generation.

Amino acids (which later combine to form proteins) are synthesized by incorporation of nitrogen, previously absorbed from the soil, with an organic unit containing carbon, hydrogen, and oxygen. In some plants this process has been demonstrated to be an integral part of photosynthesis. Various amino acids are then linked together to form proteins which participate in plant metabolism and growth as well as in seed production.

Vitamins are organic compounds of a variety of structures and elements. Photosynthesis is an essential step in their formation in plants. Further anabolic[2] steps are not fully understood but obviously include chemical reactions which fix nitrogen and other elements into the compounds.

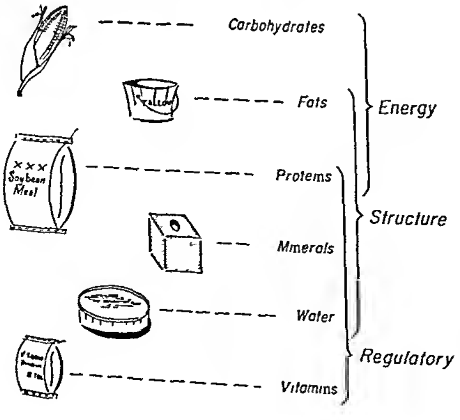
[2] Anabolism—building up of tissues or compounds in living animals or plants.

Vitamins serve important catalytic functions in plants as well as in animals promoting nutrient formation, tissue growth, and reproduction. Their presence in the plant means that harvested plants and plant products are sources of these vital nutrients.

Bacteria, yeast, and other minute forms of plant and animal life can also synthesize nutrients. Some nutrients may be produced and elaborated in surplus quantities by such organisms. Scientists have learned to harness this ability by culturing certain strains of organisms and purifying specific nutrients or nutrient combinations from the growth media. Individual amino acids and B vitamins are commercially produced in this way and sold in capsule form to humans or mixed in livestock feeds.

Certain other nutrients such as vitamin A can be chemically synthesized. Chemists first learned the chemical structure of natural vitamin A, then adapted chemical processes to produce this structure. Vitamin A manufactured chemically has the same biological effectiveness as the vitamin A converted by livestock from carotene that is present in plants.

Figure 4.2 The six classes of nutrients grouped according to their functions. There are exceptions to this generalization. Protein supplies energy only when fed in excess quantities or when rations contain insufficient carbohydrate or fat. Classes of nutrients that are considered regulatory may (1) carry nutrients, enzymes or hormones, (2) form a part of enzymes or hormones, or (3) stimulate or catalyze the activity of an enzyme or hormone in metabolism.



4.2 Classes of Nutrients

The many individual nutrients are grouped into six classes, carbohydrates, fats, proteins, water, minerals, and vitamins, according to chemical or functional similarities. Space does not permit a complete listing and discussion of all the nutrients within these classes. The main functions of the classes are illustrated in Figure 4-2.

Carbohydrates are related both chemically and functionally, they all contain the same elements and all can yield energy. Proteins also have chemical similarities, all are composed primarily of amino acids. Most proteins eventually become a part of new tissue, a hormone, or an enzyme.

Minerals are not closely related chemically except that they are individual, inorganic elements. Functions of most minerals, however, are similar. Most of them become a part of body structure and also serve to influence the rate of certain chemical reactions in body metabolism.

Further evidence of chemical and/or functional similarities among the nutrients within a class is disclosed in later sections. No attempt is made to enumerate all functions of all nutrients, or even of all classes of nutrients. Rather, *examples* are given which illustrate the types of functions which the nutrients or classes of nutrients perform.

4.3 Carbohydrates

Carbohydrates, the main source of energy in most livestock rations, make up 65 to 80 per cent of the dry weight of nearly all grains and roughages.

Energy supplied by carbohydrates is used for (1) maintenance, (2) growth, which is formation of tissue such as meat and wool, (3) reproduction, and (4) production of animal products such as milk. Energy for maintenance includes all that is used for voluntary and involuntary muscle action, such as in walking, eating, blood circulation, and movement of food through the digestive system.

Most carbohydrate energy that is not used soon after absorption is stored permanently or semi permanently in the animal by conversion to fat.

All carbohydrates contain the elements carbon, hydrogen, and oxygen. The proportion of carbon may vary, but hydrogen and oxygen are present in the same ratio as in water (H_2O). This chemical similarity and the fact that all carbohydrates have functional similarity in the ability to yield energy justifies their classification as a group.

When the chemist or nutritionist appraises the carbohydrate content of feeds, he divides this class of nutrients into two groups, "fiber" and "N F E." *Fiber* remains undissolved after a sample of feed has been washed alternately with dilute acid and dilute alkali. Since this washing simulates, to some degree, action of digestive enzymes in the intestinal tract, the fiber content roughly indicates the carbohydrates which are poorly digested and

therefore inefficient as an energy source. Cellulose, which comprises much of the woody part of a plant, is the main fiber component.

N.F.E. includes the carbohydrates which are generally easily digested and therefore relatively efficient sources of energy. Starch and sugar are examples of this group. The letters N.F.E. stand for "nitrogen free extract," adopted by feed chemists because it is a part of the feed that is free of nitrogen and is extracted by the acids and alkali used during the fiber determination.

The simple carbohydrate units (monosaccharides) which are manufactured in the plant and combined to form complex carbohydrate molecules are generally the same in both cellulose and starch. The units in cellulose, however, are *held together* by a different type of chemical bond. Enzymes of the digestive system are not as capable of breaking this bond, so the individual units are not completely released for absorption into the blood stream and utilization by the body.

Hay of average quality contains about 28 per cent fiber and 38 per cent N.F.E. Corn contains only about two per cent fiber and almost 70 per cent N.F.E. Most grains have less than 12 per cent fiber, and the N.F.E. content is usually about 60 per cent. These figures, plus the fact that grains are not as bulky as hay, explain why grains are valuable for fast gains in the feed lot, for quick fattening, and for maximum milk production. They supply a high proportion of efficiently digested carbohydrate.

Since cellulose and other fibrous carbohydrates are inefficient sources of energy for livestock, perhaps the animal nutritionist should recommend that forages with a low cellulose content be developed. The plant breeder would like to comply, except that a certain amount of cellulose is needed to keep plants standing erect for easy harvesting, exposure to needed sunlight, and maturation of seed heads.

4.4 Fats

Fats are the most *potent* energy source in rations. A pound of digested fat has about two and one quarter or more times the energy value of a pound of digested carbohydrate or protein. Most grains and roughages contain less than five per cent fat, however, so the total energy supplied by fat is not nearly as great as that supplied by carbohydrate, in most rations.

Where an extremely high energy ration is desired for broilers or swine, additional fats such as plant oils, lard, or tallow can be added. Limited quantities have been used in ruminant rations. During times when such fats are plentiful and the price is low, they often compete favorably on a "cost of energy" basis with grains.

The terms "fat" and "oil," which are scientifically known as lipids, are almost synonymous when used in reference to energy value. Oils, generally smaller in molecular weight than fats and more unstable in their natural

state, are therefore liquid at room temperature. Fats, being more stable, are usually solids at room temperature.

A feed chemist uses an ether-extraction process to measure fat or oil in a feed sample so a feed tag often lists "ether extract" instead of the word "fat."

Fats are composed of carbon, hydrogen, and oxygen, as are carbohydrates, but the proportion of oxygen is much less. This is the primary reason for the greater energy potency of fats. During metabolism in the body cells, where energy-yielding nutrients are utilized, oxydation is the process which releases energy from the nutrient. Oxygen inhaled through the lungs and transported via the blood to body cells, reacts with the nutrient and combines with the carbon and hydrogen to form the end products—carbon dioxide and water—with the simultaneous release of energy. Since fats contain little oxygen, *more* oxidation occurs and more energy is released.

A fat molecule is composed of three fatty acid units chemically united with glycerol (Figure 4-3). Fatty acids vary in size and in chemical properties. Though all can yield energy, some have other specific metabolic functions.

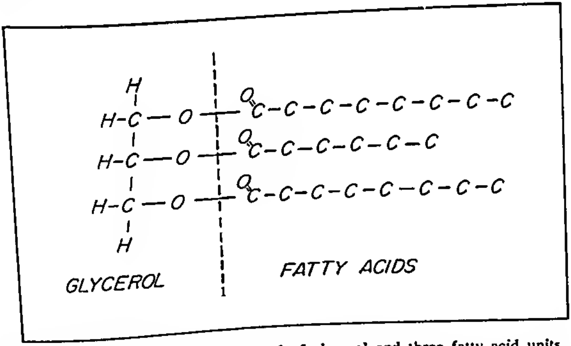


Figure 4-3. Fats are normally composed of glycerol and three fatty acid units. The fatty acid units vary in length, size, and other characteristics. All three fatty acid units which are part of a fat need not be identical.

Fat in the ration aids the absorption of vitamins A, D, E, and K from the digestive system and also carries these nutrients through the body into milk. These vitamins are therefore termed fat-soluble vitamins, though water soluble forms are also manufactured.

Fat serves to cushion and protect vital organs in the body. This fat, which physiologically is an energy storehouse, helps suspend vital organs

but also allows peristaltic[3] movement and absorbs shock and sudden movement

Fat deposits in lean muscle, which are also energy stores, add to the juiciness and flavor of steaks, chops, and roasts The term "marbling" is used by meat retailers to describe the fine dispersion of fat in the lean tissue

4.5 Proteins (Amino Acids)

Amino acids linked together form a protein Swine and other non-ruminants[4] need certain specific amino acids in their rations, and there is an optimum level of each for maximum performance Ruminants, however, have microorganisms in their digestive system which can synthesize any amino acid from other amino acids or from other sources of the needed elements In ruminant nutrition, therefore, we are concerned primarily with the *total amount of protein available* in the ration, but in nutrition of non ruminants we must be concerned with the *quantities of specific* amino acids This is why the words "Amino Acids" are prominent in the heading of this section

All amino acids contain carbon, hydrogen, oxygen, and about 16 per cent nitrogen Some contain additional elements Amino acids vary slightly in proportion of nitrogen, so proteins formed by different combinations of amino acids may also vary slightly from the 16 per cent of nitrogen An estimate of the total protein in a feed, however, is made by chemically measuring the nitrogen content and dividing by 16 per cent or multiplying by the factor, 6 25 The value which results from this calculation is called "crude" protein Some nitrogen in feeds, especially pasture and silage, is not incorporated in a protein molecule When immature plants are eaten or harvested there is considerable nitrogen present in the plant in the form of nitrates, amines, amides (small, inorganic nitrogen compounds), or individual amino acids not yet built into a protein molecule Therefore *crude* protein as measured by nitrogen content is an index to, but not a precise appraisal of, *true* protein The quantity of "nooprotein ' nitrogen in grains, formed when plants are mature, or in animal by product feeds is relatively insignificant.

It is fortunate that microorganisms (bacteria, protozoa, and others) in the rumen of cattle aod sheep can manufacture specific amino acids Most natural rations do not contain amino acids in the exact proportions needed by animals for various functions In some cases, a feed may be almost devoid of a certain necessary amioo acid The ability of the microorgaoisms

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[3] Peristaltic movements are wavelike contractions of the muscles in the walls of the hollow digestive organs These contractions force contents onward

[4] Non ruminants are animals with a single stomach compartment, such as swine and poultry (and humans) They are sometimes called monogastrics Cattle sheep and certain other animals have several stomach compartments and are called ruminants because one of the compartments is a rumen which becomes relatively large with maturity

to synthesize certain amino acids prevents nutritional deficiencies from occurring, and also allows the protein in the ration to be used most efficiently. Without these microorganisms, the protein would probably be utilized only in proportion to the level of the limiting amino acid.

This ability of the ruminant to synthesize amino acids allows the use of certain protein substitutes in cattle and sheep rations. About one third of the protein requirement of mature cattle and sheep can be supplied by nonprotein nitrogen. The most common nonprotein nitrogen source being used in feeds is urea (Figure 4-4). Microorganisms form amino acids by combining nitrogen from urea with carbon, hydrogen, and oxygen from the carbohydrate in grain or other feeds. These various amino acids are then combined into protein in bacterial tissue. The bacteria, then, become the protein source and are digested in the latter part of the digestive tract.

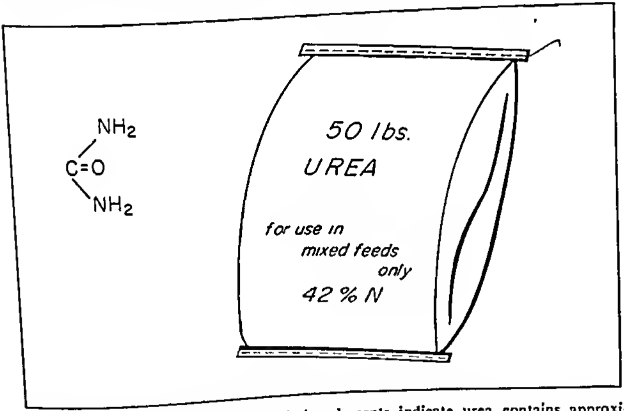


Figure 4-4. Urea. Atomic weights of the elements indicate urea contains approximately 46 per cent nitrogen. Commercial urea, however, is diluted with a carrier to make it free-flowing; therefore, it contains only about 42 per cent nitrogen.

Swine and other non-ruminants are relatively unable to utilize nonprotein nitrogen for amino acid synthesis. Certain amino acids are manufactured chemically or by cultured strains of organisms, and are added to rations low in a specific amino acid for more efficient utilization of the protein. Synthetic methionine (Figure 4-5) is commonly used in poultry rations and has also been used in dog and swine feeds. A more recently developed compound which functions like methionine but can be synthesized more cheaply is also being used.

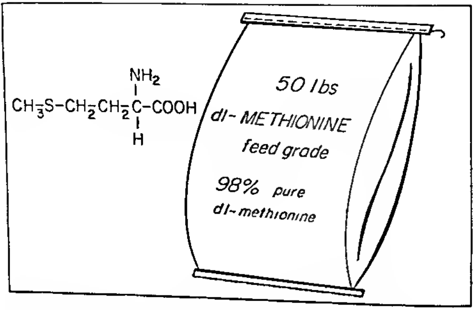


Figure 4 5 Methionine a dietary essential amino acid for non ruminants NH_2 is an amino unit and COOH is an acid unit The presence of these units on such compounds is the basis of the name amino acid

Cell walls of animals are composed primarily of protein, hence, the primary function of protein is often listed as the building and repairing of tissue Individual amino acids have many other specific and important functions Only a few examples are given here Enzymes which aid digestion in the stomach and small intestine, as well as those which catalyze metabolic reactions in body cells, are composed of amino acids One or more amino acids are essential constituents of most hormones which help to regulate body processes Certain amino acids are needed for antibody formation, others are concerned with hair and skin pigmentation

4 6 Water

Water is the cheapest nutrient Livestock normally consume three to four times as much water as feed The animal body is made up principally of water, from approximately 70 per cent at birth to slightly under 50 per cent in a market animal ready for slaughter

Water serves as a *medium* for chemical reactions—enzymatic digestion in the gastrointestinal tract and metabolism in the cells Certain enzymes are much more effective when diluted in water Water also *participates* in chemical reactions Digestion of fats, carbohydrates, and proteins is primarily hydrolysis, in which these compounds are broken into smaller units and the ions, OH— and H+ from water, are united with these units

Water circulates nutrients throughout the body and carries waste prod-

Figure 4-6. Water is the cheapest nutrient It is the major constituent of milk and of body tissues in young livestock (Union Pacific Railroad)

ucts to the site of excretion Since it circulates as part of the blood, it also helps to regulate temperature, just as water circulating through the motor and radiator of a car regulates temperature.

About ten per cent of the water used in body processes of farm animals is produced in the body cells during oxidation of energy-yielding nutrients. This results from hydrogen and oxygen atoms released during metabolism, and is called metabolic water.

An adequate supply of water that is clean and at a comfortable temperature is necessary for proper utilization of other nutrients by animals It also helps maintain good feed consumption.

In general the extra water in certain "wet" feeds is of no special nutritional value. It merely replaces water the animal otherwise would drink from a tank. Immature pasture grass may contain up to 80 per cent water; silages usually have 65 to 75 per cent Most hay and grain stored in an air-dry condition contain only 10 to 14 per cent water (moisture).

4.7 Minerals

Minerals are inorganic elements Organic compounds, which contain carbon (such as carbohydrates, fat, protein, and vitamins), will burn When a sample of feed is burned at 600°C. until it ceases to lose weight, the minerals remain as ashes. Hence, the word "ash" on a feed tag refers to the total mineral content.

Minerals become a part of skeletal structure, but also play essential roles in digestion and in metabolism inside body cells Calcium, phosphorus, magnesium, fluorine, and certain other mineral elements are integral parts of the bone structure and of teeth Approximately 99 per cent of the calcium and 80 per cent of the phosphorus present in the animal body is contained in the skeleton When the need arises, calcium and other minerals can be mobilized from the skeleton and used for other body functions Examples are the removal of calcium for egg shells when a pullet first begins to lay, or for milk production after a heifer or cow calves Excess calcium, consumed before these production needs exist, is temporarily stored in the skeleton

Mineral functions in digestion and cell metabolism are not as familiar to most people, but are equally essential Simple sugars which result from carbohydrate digestion, and fatty acids released by digestion of fats, must be combined with a phosphorus compound in the intestine before they can be absorbed through the intestinal and capillary walls into the blood stream

Calcium plays a role in blood coagulation, and also serves as a catalyst in oxidation of nutrients in cells to yield energy Sodium, from salt, and potassium help to stabilize osmotic pressure inside and outside of blood cells and muscle cells, to keep them from shrinking or bursting

Certain mineral elements are integral parts of key body compounds Iron copper, and cobalt are involved in the synthesis of hemoglobin, the red blood pigment responsible for transport of oxygen from the lungs to body tissues Iodine is an integral part of the hormone, thyroxine Zinc is a component of insulin, which controls the rate of carbohydrate utilization Other examples could also be given

Microorganisms functioning in the digestive system of ruminants have a need for certain minerals Many, including phosphorus and iron, have been shown to be critical[5] in bacterial digestion of roughages Certain minerals are also needed for the synthesis of amino acids and B vitamins Sulfur must be available for synthesis of methionine, cobalt is an essential constituent of vitamin B_{12}

The above does not include all of the functions of minerals in livestock rations Instead, it merely illustrates the *types of roles* that minerals perform Minerals which serve as catalysts in digestion and metabolism are needed in very small quantities Skeletal requirements for minerals are large, however, as indicated by the proportions of body calcium and phosphorus contained in the skeleton

Many minerals are present in grains and roughages The content depends on the species, the soil on which the crop is grown, the stage at harvest, and other factors Most rations composed of plant ingredients and various by-product feeds are short in sodium, calcium, and phosphorus Salt should

[5] Critical is used to mean that not only is the nutrient essential but also that normal rations may often supply insufficient quantities

therefore be supplied to livestock either free-choice or added at about 0.5 per cent of the ration, as a source of sodium. Limestone, containing 39 per cent calcium, and bonemeal, dicalcium phosphate, or other products which supply both calcium and phosphorus, are often added to livestock rations. Potassium, manganese, and magnesium are sometimes considered critical in rations for non-ruminants (Table 6-2). Extra iodine is needed for all livestock where soils are deficient in iodine. Except for bonemeal, a by-product of the meat processing industry, nearly all *supplemental* minerals are mined from underground deposits.

Certain minerals, such as selenium, can be toxic to livestock if present at extremely high levels in soils and plants. High levels of fluorine and molybdenum are also toxic, even though a certain amount of each is essential for body functions.

4.8 Vitamins

Vitamins are essential organic nutrients that are not needed for energy or as a source of nitrogen. Their role is mainly catalytic; hence they are required in small quantities. About .01 grams (.000022 pounds) vitamin B_{12}, for example, is enough for a ton of hog ration.

The word "vitamin" was coined in the early part of the twentieth century when it was presumed that these essential food constituents required in minute quantities were amines. The term "vital amine" was abbreviated to form the word vitamin. We now realize that the various vitamins are not amines but the word has continued to be used and is now a part of our vocabulary. Vitamins are not necessarily related to each other chemically or functionally. They are classed together only because their functions are mainly of a regulatory nature; each has specific and separate functions.

About 15 different vitamins are recognized to exist and to have specific functions in animal metabolism. *Not all* must be present in rations of livestock, however, because synthesis of certain vitamins can occur in various parts of the animal body.

Farm animals rarely need a dietary source of vitamin C. It is synthesized in ample quantities in animal tissues.

Vitamin K is produced by bacteria in the digestive system and a dietary source is usually not needed, except in newborn animals or animals with extreme diarrhea or digestive disturbances. Since a calf, lamb, or pig develops in and is born from the sterile uterus, several days elapse before the bacterial population of the digestive system develops so that ample vitamin K can be produced. Some is stored in the liver before the animal is born, and milk supplies additional quantities until intestinal synthesis becomes adequate.

Adult ruminants generally do not have a dietary requirement for B vitamins (thiamin, riboflavin, niacin, pantothenic acid, pyridoxine, B_{12} and

others) Microorganisms in the rumen synthesize these from other nutrients and elements, making them available for absorption into the blood circulatory system

Since ample quantities of vitamin E are normally present in natural feeds, the practical concern about vitamins is narrowed down to *vitamins A and D for ruminants* and these, *plus certain B vitamins, for non ruminants* (Tables 6-2 and 7-2)

Green forage and animal products, especially liver, are good sources of vitamin A Dry, weathered grass and hay are very low in vitamin A potency Deficiencies of this vitamin often occur, therefore, during periods of prolonged drouth in range areas Carotene and other plant pigments are the source of vitamin A potency in green forages After the forage is ingested, these compounds are converted to vitamin A in the wall of the small intestine and in other tissues Carotene in hay is partially destroyed by exposure to the sun during curing Other factors, such as extreme heat and high concentration of minerals in feed, will destroy some of the vitamin A potency

The rearing of animals such as broilers, dairy calves, and pigs in confinement increases the need for vitamin D in livestock rations As long as animals are exposed to the sun, ultraviolet rays catalyze the formation of vitamin D from certain compounds present just under the skin Animals raised or kept inside, however, must depend on their rations to supply adequate vitamin D

Vitamin D will be formed in plants only after the plant has matured or has been cut and lies exposed to the ultraviolet rays of the sun Growing pastures therefore are low in vitamin D, while sun cured hay is relatively high The ultraviolet rays of the sun catalyze the formation of vitamin D in plants the same as in animals It is interesting to note here that cut hay, exposed to the sun for curing, *loses some vitamin A*, but becomes a *more potent source* of vitamin D

Concentrated sources of vitamin D for supplementing livestock feeds, as well as human diets, are manufactured by exposure of yeast (single-celled plants) to ultraviolet rays

B vitamins are supplied by green, good quality forage, animal by-products, and milk products Fermentation by products, from the cheese, brewing, or distilling industry, are also good sources (Figure 4-7)

Most vitamins function primarily as regulators of body metabolism *Examples* of some known vitamin functions are given below

In addition to its function in transmission of light received in the eye, vitamin A is concerned with the nervous system, the epithelium, and the reproductive tracts of the male and female, as well as with fat metabolism

Vitamin D is essential for many functions, including (1) calcium absorption, (2) calcium deposition in bones, (3) storage of carbohydrate in the liver and cell, (4) excretion of protein end products through the kidney,

Figure 4-7. B vitamins are produced by biological fermentation in stainless steel tanks The fermentation product is dried, then standardized for potency, and sold for mixing in livestock feeds (Commercial Solvents Corp)

and (5) oxidation of fats and carbohydrates to supply energy. Coagulation of blood requires vitamin K in addition to the mineral calcium Ample vitamin K must be in the liver to cause formation of certain materials which later participate in the coagulating process.

Vitamin E is apparently needed to maintain the integrity of the blood capillaries; vitamin C is involved with mineral deposition in the bones and also with healing of wounds.

Members of the B vitamin group are generally employed in animal tissues for releasing energy from the carbohydrates, fats, and proteins, breaking down ingested proteins and amino acids, and recombining these units into body protein. They also help maintain the nervous system and the epithelium tissues. Each member of the group has separate and distinct functions, some of which are not included above Certain B vitamins stimulate appetite and are needed to maintain good feed consumption in nonruminant animals. Supplemental levels of B vitamins are sometimes used for this purpose during exteremly hot weather when feed consumption normally declines.

Vitamins probably have many specific functions that are not known. A clue to some of these is provided by symptoms which occur during a deficiency of the specific vitamin.

4.9 Unidentified Factors

In addition to recognized nutrients there apparently are other factors present in certain feeds and materials that enhance the growth and per-

formance of livestock Until these factors are chemically identified or defined, they are referred to as unidentified factors

During the latter part of the nineteenth century, a then unidentified factor in rice polishings was known to cure beriberi in man This factor, identified only after continued research, is now known as thiamin Similar examples during the first half of the twentieth century could be presented for most vitamins we now recognize and also for other nutrients and feed additives

Vitamin B_{12}, isolated chemically in 1948, is a recent and dramatic example Liver had long been known to contain an "antipernicious anemia factor" By 1945 it was generally accepted that a certain factor (or factors) needed for growth of chicks was present in animal by-product feeds but not in rations composed only of plant materials This factor was designated "animal protein factor" (APF), "chick growth factor," or "factor X" It was also demonstrated to be in milk, commercial casein, and liver extract Following isolation of vitamin B_{12}, continued research demonstrated that the "factors" in these four products were the same compound

In some cases alleged or suspected unidentified factors beneficial to animal production have later been demonstrated to be nutrients or combinations of nutrients already known The beneficial influence of alfalfa on ruminant digestion, when recommended levels of known nutrients were previously included in the ration, suggested the presence of an additional unidentified factor in alfalfa Later research indicated, however, that extra iron and other mineral components in alfalfa were causing the benefit, and that the requirement for these minerals was higher for optimum rumen function than previously believed

Some factors which have had apparent benefit on animal performance have, after continued research, been identified as specific compounds which are not nutrients These materials have not been demonstrated to be essential for normal growth and reproduction but rather play some other beneficial role, such as suppressing disease organisms or inhibiting competitors for nutrients For some of these, the specific mode of action has not been learned

This pattern—realization of the presence of an unidentified beneficial factor, and later isolation of the compound—probably will be repeated in the future as it has in the past Our knowledge of nutrients and nutrition will continue to develop

4 10 Non-Nutrient Feed Additives

Many non nutrient compounds are now added to livestock feeds to promote growth and production, stabilize nutrients in feed, improve feed utilization, or help prevent the stress of infections and disease These compounds are not classed as nutrients because they are not essential for normal metabolism, growth, and reproduction

Certain of these compounds, though beneficial at recommended levels, may be harmful at high levels or when handled by people not familiar with their effects, so federal and state feed control officials supervise their use in livestock feeds. Antibiotics, detergents, compounds with hormonal properties, bacteriostatic agents, antioxidants, and others are included in the group which feed control officials normally refer to as "drugs." Approximately 50 such drugs are currently being used in mixed feeds.

Effects and recommended levels of a few additives will be discussed in later sections.

5

THE DIGESTIVE AND METABOLIC SYSTEMS

How does an animal utilize the nutrients in feed it consumes? What are the mechanisms for releasing specific nutrients from complex feeds, and moving these nutrients into organs and cells of the body where they can become part of the animal structure, contribute to animal life, or help form animal products? Meat, milk, and eggs, as well as such nonedible products as wool and leather, are the eventual result of nutrient utilization—digestion, absorption, circulation, and metabolism

Digestion includes the physical and chemical changes which feeds undergo in the gastrointestinal tract (mouth, esophagus, stomach, and intestines) and releases the individual nutrients for absorption Chewing, swallowing, and rhythmic movements of the stomach and small intestine cause physical breakdown of feed particles into smaller pieces, increasing the surface area exposed for chemical digestion *Emulsification* of fat by bile in the small intestine is a part of the physical breakdown

Chemical changes in feeds are accomplished by secreted enzymes[1] and also, to varying degrees, by bacteria and other microorganisms present in these digestive organs Enzymes catalyze hydrolysis of carbohydrates, fats, and proteins into smaller units that can be absorbed

Most *absorption* of nutrients occurs from the small intestine, through the intestinal wall and blood or lymph capillary walls, to the circulatory system Absorbed nutrients are *circulated* to individual cells where they are finally utilized

A "cell" may refer to a typical muscle cell, liver cell, kidney cell, or cell of some other tissue Cells which comprise organs have specific functions and utilize absorbed nutrients for these functions

In these cells *metabolism* occurs Carbohydrates and fats are further degraded to yield energy Amino acids are recombined to form protein and eventually, lean muscle tissue, hormones or enzymes Vitamins and minerals also function here in the utilization of carbohydrates, fats, and proteins

[1] Enzymes are organic catalysts They promote changes in other organic compounds without themselves being changed All known enzymes that have been studied are composed of amino acids

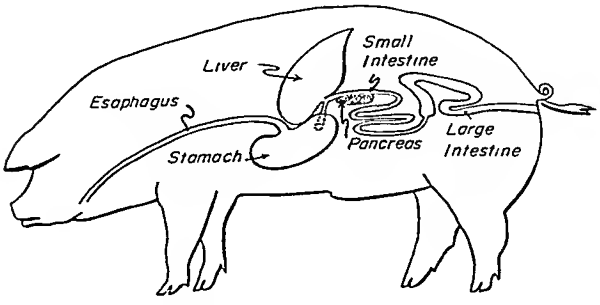
It is important to realize that utilization of a ration by farm livestock involves four steps: (1) digestion, (2) absorption, (3) circulation of absorbed nutrients, and (4) cellular metabolism. Following is a brief discussion of these steps considering the organs and tissues involved as well as the differences among species. Digestion and absorption in non-ruminants will be emphasized in the first sections; then the unique characteristics of the ruminant digestive system will be discussed.

5.1 Non-Ruminant Digestive System

Non-ruminants, such as swine, and poultry (and humans), have a single stomach compartment. Young calves and lambs are functionally non-ruminants until the accessory stomach compartments develop and begin to actively aid digestion. This is a gradual process; the additional stomach compartments are not completely functional until the animal is several months of age.

The non-ruminant digestive system, including accessory organs, the liver and pancreas, is diagrammatically illustrated in Figure 5-1. Note the small stomach volume of the pig, in relation to the animal's size. This small size dictates frequent feeding and the use of a concentrated ration low in bulkiness and fiber. A two-week-old pig has a stomach capacity of only about 0.7 pounds; the stomach of a 200-pound pig will hold about 8.5 pounds. Total capacity of the four stomach compartments of a 100-pound lamb, however, is about three gallons (24 pounds).

Figure 5-1. A diagrammatic outline of the digestive system of the pig. The intestines, of course, are much longer than illustrated.



5.2 Mastication

Mastication, the mechanical breakdown of feeds into smaller particles, increases the area exposed for more complete enzyme action in the mouth, stomach and small intestine A pig has a full set of incisors and molars for complete and effective chewing Cattle and sheep have only a dental pad instead of top incisors However, since molars do most of the grinding, mastication of rations by these animals can be very effective

The action of the tongue and of swallowing contribute to mastication because of the abrasion of particles with others and with the lining of the esophagus Peristaltic action which moves the mass of ingesta along the digestive tract, may also cause mechanical breakdown

Bile, produced by the liver and temporarily stored in the gall bladder, flows into the small intestine to emulsify fats Emulsification breaks fats into tiny units, increasing the surface area for more effective enzyme action Mechanical breakdown, then, continues even after chemical digestion by enzymes has begun

Since poultry do not have teeth, they depend on the gizzard for mechanical breakdown of feed particles A rough inner lining presence of grit as grinding stones, and strong muscular action insure thorough grinding

5.3 Enzymatic Digestion

Enzymatic digestion of feeds, releasing nutrients, begins in the mouth Saliva elaborated from several sets of glands there, contains a carbohydrase[2] which catalyzes digestion of carbohydrates This digestion is not completed in the mouth but enough does occur to release a few simple sugars, giving a sweet sensation with certain feeds The saliva of cattle and sheep apparently contains no carbohydrase

Since saliva and ingested feed are mixed thoroughly during chewing, the carbohydrase (in non ruminants) continues to hydrolyze carbohydrates as the feed is swallowed and even after it enters the stomach Presence of feed in the stomach stimulates secretion of hydrochloric acid which, in time, lowers the pH of the stomach contents and stops the action of ptyalin

Special cells in the stomach lining secrete proteases which hydrolyze proteins into smaller units, polypeptides, dipeptides, and/or amino acids A

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[2] Carbohydrase—an enzyme which catalyzes or promotes the hydrolytic digestion of carbohydrates The term denotes a class of enzymes, all of which attack carbohydrates. The carbohydrase in saliva, ptyalin is a relatively nonspecific carbohydrase and causes hydrolysis of most carbohydrates Certain other carbohydrases will cause hydrolysis of only certain specific types of carbohydrates Carbohydrases are often called amylases.

Digestive enzymes generally are named according to the type of compound they work on, plus the "ase" suffix. Proteases catalyze digestion of proteins and lipases catalyze digestion of lipids

polypeptide is a combination of several amino acids, but is smaller than a protein; a dipeptide contains two amino acids. Efficient absorption of nutrients is dependent on the continuation of digestion until the smallest units which comprise carbohydrates, fats, and proteins are eventually broken apart. Amino acids apparently are absorbed *most* efficiently through the wall of the small intestine but *some* dipeptides, especially those composed of amino acids small in molecular weight and therefore small in size are also absorbed.

Proteases in the small intestine, produced there and in the pancreas, continue the protein hydrolysis initiated in the stomach. Carbohydrases produced by the pancreas continue the carbohydrate digestion, releasing monosaccharides (simple sugars) for absorption.

Fat digestion begins in the small intestine. Following emulsification by bile, pancreatic lipase hydrolyzes much of the fat to the component parts, glycerol and fatty acids. Fats of low molecular weight, which contain small, short-chain fatty acids, can be absorbed without complete hydrolysis. Efficient absorption of other fats, however, depends on enzymatic digestion.

It is interesting that enzymatic digestion of the most plentiful nutrient in livestock rations, carbohydrate, begins in the mouth. Protein digestion begins in the stomach and digestion of fats is initiated in the small intestine, the organ from which most absorption occurs. A typical swine ration contains approximately 60 per cent carbohydrate, 15 per cent protein, and three per cent fat. During evolution there have developed animals and feeds that are compatible. Lengthy enzymatic treatment is provided for carbohydrates, beginning in the mouth and continuing to the site of absorption. Fat, present in smaller quantities and not requiring complete hydrolysis for absorption, receives less thorough digestive action.

5.4 Absorption

Nutrient absorption into the circulatory system is not a simple filtration process for most nutrients. It is an active process occurring only in living tissues and requiring certain specific conditions. Efficient absorption of many nutrients is dependent on the presence of other nutrients, the rate that ingesta[3] is moving through the tract, and other factors.

Most absorption in non-ruminants (and much in ruminants) occurs from the small intestine, where enzymatic digestion reaches a climax. The small intestine is a long organ so nutrients released there can be absorbed before ingesta is moved on to the large intestine. The small intestine of a 100-pound pig, for example, is about 60 feet long. Little absorption, except for water and some small fatty acids, takes place from the stomach or large intestine.

[3] Ingesta—a mixture of consumed feed, saliva, other enzyme-containing digestive juices, and/or microorganisms present in the digestive tract.

Villi minute proliferations of the small intestine lining provide an extremely large surface area for active absorption Each villus contains an elaborate network of capillaries so that only two cellular membranes separate the digested nutrients in the intestine from the circulating fluids in the blood or lymph capillaries

Absorption of monosaccharides the simple sugars resulting from carbohydrate digestion, involves phosphorylation or combination with a phosphorus-containing unit After this combination moves through the membranes and into the circulatory system dephosphorylation occurs The phosphorus unit can be used again, and the monosaccharide is carried to the liver or other cells for utilization Evidence indicates that absorption of amino acids, fatty acids, and glycerol occurs similarly

Minerals, being single elements apparently are absorbed by simple filtration or by a process controlled by osmotic pressure In certain cases minerals in feeds are held in complex compounds not completely digestible, so are relatively unavailable for absorption Over half the phosphorus in grains is contained in such a compound called phytin It is not absorbed and utilized by poultry, and may be only partially utilized by swine Bacteria in the rumen apparently produce enzymes capable of breaking the phytin complex, releasing some of the phosphorus for absorption

Certain feeds contain high levels of oxalates, organic compounds which tie up calcium rendering it unavailable for absorption

Mechanisms for vitamin absorption are not completely understood It is presumed to be an active process rather than filtration and certain conditions are known to favor or inhibit effective absorption It is conceivable that under certain conditions vitamins might be destroyed by digestive enzymes before they reach the site of absorption

5 5 Ruminant Digestive System

Mature cattle and sheep, as well as certain game animals, have four functional stomach compartments, the rumen, reticulum, omasum, and abomasum These compartments are illustrated in Figure 5-2 Because the fourth compartment, the abomasum, corresponds to the stomach of nonruminants, it is called the "true stomach"

Table 5 1 Approximate Relative Capacity of Ruminant Stomach Compartments

Compartment	At birth, (%)	At 4 months, (%)	At Maturity,
Rumen	25	75	80
Reticulum	5	5	5
Omasum	10	9	7
Abomasum	60	11	8
	100	100	100

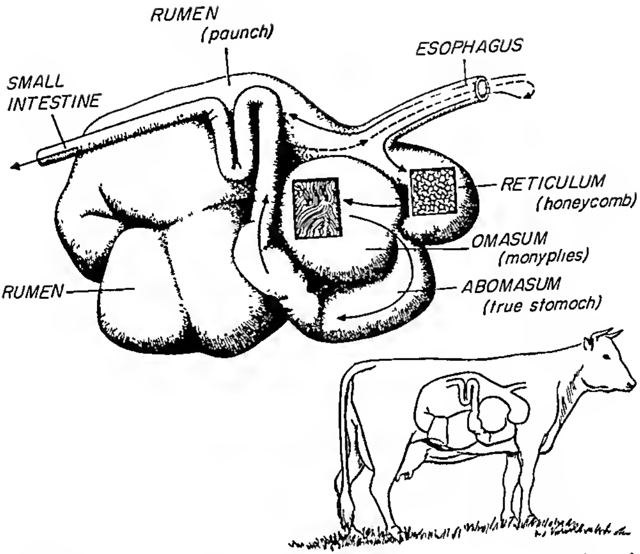


Figure 5-2. The ruminant digestive system. The cut-away view shows the linings of the reticulum and omasum.

Development of the ruminant digestive system is gradual. When calves and lambs are born they are functionally non-ruminants, since the first three compartments are relatively small. These compartments grow faster than the true stomach, as indicated in Table 5-1, and gradually begin to function.

Before the various compartments and their fuctions are discussed in detail, other differences between ruminants and non-ruminants should be mentioned. Cattle and sheep do not have incisors on the upper jaw, only a dental pad. There is no apparent advantage to this; these animals simply do not seem to need upper incisors. Forage, natural feed for ruminants, is easily severed from the growing plant without the upper incisors.

Cattle and sheep swallow ingested feed almost immediately with very little chewing. They graze or consume harvested forage for long periods without apparent interruption. Later they lie down in a pleasant spot to "chew their cud." Previously consumed feed is regurgitated into the mouth for thorough chewing. This bolus or mass of ingesta is more thoroughly masticated, then swallowed, and another bolus is regurgitated. This continues until the mechanical breakdown of the usually fibrous feed is rela-

tively complete Since each bolus of feed is swallowed into the rumen and mixed with other ingesta it is probable that many individual feed particles are regurgitated, chewed, and swallowed several times

Regurgitation described here does not involve the bitter sensation experienced by humans and other non ruminants The bolus of feed regurgitated by a steer comes from the rumen, which is almost neutral in pH, not from the acidic true stomach

The *rumen* the largest of the four compartments and the one to which most bulky feed first goes, functions as a large fermentation vat Since no digestive enzymes are produced in the walls of the rumen and the saliva of cattle and sheep apparently contains no carbohydrase, enzymatic digestion occurring in the rumen is almost completely the result of bacterial and protozoal enzymes

Millions of bacteria, protozoa, and other minute organisms flourish here in a mass of water and feed These organisms secrete enzymes which digest carbohydrates and proteins, they synthesize B vitamins, and they reproduce and grow, incorporating amino acids, other nitrogen compounds, or elemental nitrogen into bacterial cells which are protein for the host animal

Most of the digested carbohydrate in ruminant rations is degraded by organisms in the rumen to acetic, propionic, and butyric acids (sometimes called volatile fatty acids) These small compounds are absorbed directly through the rumen wall into capillaries of the circulatory system A small amount of the carbohydrate is incorporated into organisms as their energy store When these organisms reach the small intestine, enzymatic digestion releases this carbohydrate and the amino acids comprising the organism structure for absorption

Other items—minerals, water, and glucose, an intermediate in rumen digestion of carbohydrate—are absorbed through the rumen wall into the circulatory system

Since the smaller reticulum is completely open to the rumen, fermentation occurs here too, and ingesta moves back and forth with the rhythmic movements of rumination The reticulum lining, however, appears like the surface of a honeycomb Rumination apparently causes movement of the smaller food particles into the omasum, the third compartment

As indicated in Figure 5-2, the omasum is comprised of a mass of suspended, adjacent, and parallel leaves with very coarse surfaces These leaves, with the aid of regular movements of the organ, may cause some grinding or crushing of ingesta, but also permit absorption of massive quantities of water

The first three compartments of the ruminant stomach are designed so the animal can utilize roughage as the main nutrient source for normal growth and reproduction They provide for (1) some mechanical breakdown, (2) bacterial digestion, especially of cellulose which is the main

constituent of fiber, (3) formation of bacterial protein which supplies the needed balance of amino acids, and (4) formation of B vitamins.

5.6 Circulation of Nutrients

Absorbed nutrients are carried by the blood and lymph to organs and tissues throughout the body. The lymphatic vessels generally parallel the veinous portion of the blood system.

Most of the blood leaving the absorptive area of the intestine eventually enters the portal vein leading to the liver. The liver is not only an active site of metabolism—degrading and rebuilding amino acids, detoxifying excretion products, building blood cells, and performing dozens of other vital functions—but is also a storehouse for all classes of nutrients.

The complete circulatory system, which reaches and bathes every cell in a circulatory fluid, is a most efficient nutrient distribution system. In a healthy animal the need for a nutrient in any cell is almost immediately met, if the nutrient is available in adequate quantities. The communication media for this distribution system is primarily the profuse nervous system. Hormones and other factors contribute to the regulation of nutrient use and distribution by providing stimuli for this nervous system.

5.7 Nutrient Storage

Intake of nutrients in the form of livestock rations is not continuous, nor is it always uniform through succeeding days, weeks, or months. Nor is the *demand* for nutrients within the animal body continuous or uniform. Just as cities build reservoirs to guarantee a water supply between rains, the animal body is equipped to store, temporarily or semipermanently, essential nutrients.

Calcium, phosphorus, and other minerals are stored in bones and teeth. These deposits accumulate while a dairy cow is "dry" or before a pullet begins to lay, and are mobilized when the need arises. Each egg shell contains about two grams of calcium, more than a laying hen would normally consume per day, so the extra bone storage is essential.

The liver is also an important site of nutrient storage. This storage function is reflected in the high nutritional value of liver meal, a by-product of the meat processing industry. Human nutritionists also recognize the value of liver in the diet.

Vitamin A, B vitamins, essential amino acids, and carbohydrates are among the nutrients temporarily stored in the liver. Liver storage of vitamin A, accumulated by a cow during the summer on green pasture, provides a continuous supply of the nutrient during the long winter when she may receive only weathered roughage low in vitamin A potency. Carbohydrate in the liver is a "quick-energy" reserve that can be mobilized quickly.

Newborn animals depend on liver nutrients, stored during embryonic development, for survival

Every body cell maintains some nutrient storage which may be small or large, depending on the type and function of the cell, and on the particular nutrient being stored Active muscle cells in the arms, legs, and jaws must maintain carbohydrate stores, plus certain B vitamins, vitamin D, and minerals employed in the energy releasing oxidative process needed for muscle contraction Bone marrow cells, which manufacture hemoglobin for red blood cells store and use amino acids, iron, copper, cobalt, folic acid, and other nutrients, in addition to carbohydrate

Adipose and subcutaneous tissue cells are primarily energy storage cells where little active metabolism occurs Fat, from absorption or converted from excess carbohydrate, occupies these cells as the main form of energy storage in animals

5 8 Nutrient Utilization in the Cell

Nutrients do their job *inside* a cell Most energy yielding nutrients, such as monosaccharides and fatty acids, are oxidized or burned inside body cells This oxidation obviously does not involve burning at the high temperature of a bonfire Rather, enzymes within each cell (different enzymes than those present in the digestive system, but with somewhat related functions) promote this oxidation, permitting it to proceed at body temperature This oxidation, the reverse of plant photosynthesis, releases energy and gives off carbon dioxide and water as end products

$$6\,CO_2 + 6\,H_2O + \underset{\text{(673 Calories)}}{\text{Radiant Energy}} \xrightarrow[\text{Chlorophyl}]{\boxed{\text{Photosynthesis}}} C_6H_{12}O_6 + 6\,O_2$$

$$C_6H_{12}O_6 + 6\,O_2 \xrightarrow[\text{Cell Enzymes}]{\boxed{\text{Oxidation}}} 6\,CO_2 + 6\,H_2O + \underset{\text{(673 Calories)}}{\text{Radiant Energy}}$$

The released energy is then stored in intermediate compounds for later use in maintenance, growth, reproduction, and production of animal products In a steer being fattened for slaughter on a full feed of grain, much of the energy is not released by oxidation, but is deposited in cells as fat molecules

Amino acids, released from whole proteins by digestion in the small intestine, then absorbed and transported to cells become a part of the cell structure allowing it to grow or divide Muscle development therefore is primarily amino acid or protein deposition Certain amino acids become a part of the pigmentation molecules in hair or skin cells Others are used in glands and organs to build hormones or enzymes

Excess protein in the diet, above that needed for specific protein functions, is usually converted in the liver to an energy-yielding compound. Such protein is not necessarily harmful, but is expensive. Protein in animal rations, from oilmeals or animal by-products, invariably is more expensive than the normal energy sources, carbohydrate and fat in grains.

Most other nutrients, besides calcium, phosphorus, and others which become a part of skeletal structure, play their role in the various cells by helping release energy from carbohydrates or fats, or by promoting the build-up of amino acid-containing tissues and products. Some examples of these functions have been previously cited.

6

NUTRITION OF NON-RUMINANT ANIMALS

Farm animals with one stomach compartment—swine and poultry, as well as calves and lambs up to several months of age—usually need a concentrated ration. The ration must be low in fiber and highly digestible, since these animals have a small stomach capacity and are without the large numbers of microorganisms needed for bacterial digestion of fibrous feeds. These animals, especially swine and poultry, grow and mature fast so the requirements for energy and other nutrients are high in relation to feed consumption and capacity.

The most common feeds for swine and other non ruminants are *concentrates*, defined as feeds low in fiber (usually under 12 per cent) and high in digestible energy. Concentrates may be *high* or *low* in protein. Grains usually contain only 8 to 14 per cent protein and are fed primarily to supply *energy*. Molasses, sugar, and animal or plant fats are good energy sources almost devoid of protein. Most other concentrates, such as oilmeals and most meat, dairy, and fish by-products, contain 20 to 60 per cent protein. A few, such as blood meal, have 80 per cent or more protein.

Concentrated rations, amply fortified with needed nutrients and feed additives, cause rapid gains. Swine and poultry are usually fed for a fast trip to market or for top production since every day in the feed lot or growing house means feed is being used to *maintain* the animal. Risk of sickness and death continues until animals are marketed, as does the payment of interest on money borrowed to finance the livestock operation. Faster gains and quicker marketing also mean more efficient use of facilities, since more hogs, broilers, or poults can be fed to market weight during the year. In addition, producers often hope to market early, before a "seasonal" decrease in price (Figure 6-1).

What about sows that aren't necessarily fed for most rapid gains? In sow rations *roughages*, feeds high in fiber and low in digestible energy, are often used *with* concentrates. Such roughages include ground alfalfa hay or meal, silage, pasture, and other forages. These feeds are bulky and are not efficiently utilized by non ruminants. When roughages comprise a substantial part of the ration, a pregnant sow cannot consume as much usable energy in a day as if the ration were composed entirely of concentrates. This prevents the sow from getting too fat for maximum reproduction. The same re-

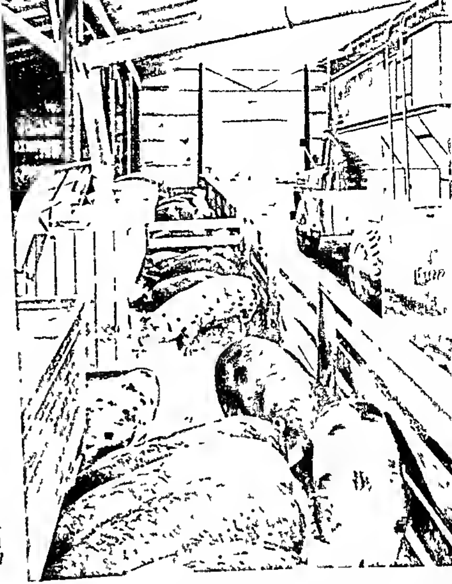


Figure 6-1. An increasing percentage of hogs are fed complete rations, with ingredients ground, mixed, and often pelleted (*Successful Farming*)

sult can be accomplished by hand feeding a limited quantity of a concentrated ration, but this requires extra labor. And roughage is often a cheaper source of energy on farms than grain

6.1 Nutrient Requirements

Nutrient levels for non-ruminant rations are usually stated as a proportion of the ration. Protein and mineral requirements (except for a few trace minerals) are stated as a percentage of the ration, and the requirements for vitamins are expressed as units, milligrams, or micrograms per pound of ration (Table 6-1).

The need for most nutrients is influenced by the volume of feed consumed (intake of *other* nutrients). Protein needs increase with feed consumption because protein comprises the enzymes which metabolize energy-yielding nutrients inside cells. Protein is used to replace tissue scraped from the lining of the digestive tract by food movement through the tract. The greater the feed consumption, the more protein is needed for this purpose.

Phosphorus needs are related to carbohydrate and fat intake. Much of the phosphorus is used for carbohydrate and fat absorption, and for metabolism of these nutrients in the cells. Also, if an animal consumes more feed and grows faster, proportionally more phosphorus and calcium are needed

Table 6 1 Minimum Nutrient Requirements of Certain Non Ruminants

Nutrient	Starting chickens,[1] 0-8 weeks	Swine[2]			Calves,[3] 75-100 lbs	Lambs, 25 lbs
		25 lbs	100 lbs	200 lbs		
Crude protein, per cent	20 0	17 00	13 00	12 00	25 00[4]	—
Calcium, per cent	1 0	0 65	0 50	0 50	0 77	—
Phosphorus per cent	0 6	0 50	0 40	0 40	0 68	—
Salt, per cent	0 4	0 50	0 50	0 50	(0 50)	—
Potassium, per cent	0 2	(0 25)[5]	(0 25)	(0 25)	—	—
Manganese, mg./lb	25 0	(18 00)	(18 00)	(18 00)	(7 00)	—
Iodine, mg./lb	0 5	(0 10)	(0 10)	(0 10)	—	—
Magnesium mg./lb	220 0	(181 00)	—[6]	—	(250 00)	—
Vitamin A U./lb	1,200 0	600 00	400 00	400 00	800 00[7]	—
Vitamin D, U./lb [8]	90 0	90 00	60 00	60 00	150 00	—
Thiamin mg./lb	0 8	0 50	0 50	0 50	—	—
Riboflavin, mg./lb	1 3	1 40	1 00	1 00	—	—
Niacin, mg./lb	12 0	8 00	5 00	5 00	—	—
Pantothenic acid mg./lb	4 2	5 00	4 50	4 50	—	—
Choline mg./lb	600 0	400 00	(300 00)	(300 00)	—	—
Pyridoxine, mg./lb	1 3	0 50	—	—	—	—
Vitamin B_{12}, mcg./lb	4 0	7 00	5 00	5 00	—	—

[1] National Research Council Publication *Nutrient Requirements of Poultry* 1960
[2] National Research Council Publication *Nutrient Requirements of Swine* 1959
[3] National Research Council Publication *Nutrient Requirements of Dairy Cattle* 1956
[4] A calculated value assuming protein fed is 80 per cent digestible
[5] Figures in parentheses are estimates based on scanty research information
[6] A void indicates the minimal requirement has not been established and/or natural rations contain sufficient quantities of the nutrient Essentially no research has been done on nutritive requirements of baby lambs
[7] Calculated from carotene assuming one mg carotene equals 400 units vitamin A
[8] Vitamin D_3 for chickens vitamin D_2 for swine and calves

for skeletal growth. The need for many B vitamins is related to intake of energy-yielding nutrients.

This system of expressing nutritive requirements as a proportion of the ration is usually much simpler and more usable in formulating rations than expressing requirements on a "per day" basis. The per day requirement for a 100-pound pig is obviously much greater, for most nutrients, than the per day requirement for a 50-pound pig. Requirements for these two animals are very similar, however, when expressed as a percentage of the ration.

There are exceptions to the generalization that nutrient requirements are proportional to feed intake. Vitamin A, for example, functions in normal vision and helps maintain the integrity of epithelium covering the skin and the linings of the male and female reproductive tracts. Vitamin D also has some functions that are not directly related to feed consumption.

Effective levels of certain non-nutrient feed additives are not necessarily influenced by level of feed consumption. Antibiotics, for example, are of greatest benefit to young animals because they are more susceptible to and affected by environmental stresses such as disease. Hence, higher levels of antibiotics or similar additives are usually used in rations for very young animals.

Even though the most effective antibiotic level and some vitamin requirements are not related directly to feed intake, the recommended allowances are usually stated as a proportion of the ration, *for certain weight pigs*, because most feed additives and supplemental vitamins are mixed in and administered via the ration.

How are nutrient requirements of animals established? There are several techniques used by college and university experiment stations and by federal and private research agencies, usually involving large numbers of animals. Animals may be fed individually, or in small groups, rations containing graded levels of the nutrient in question, for instance protein. Precautions include that the rations *be adequate* in all nutrients except protein; that all animals, or groups of animals, be as uniform in breeding, weight, nutritional history, etc., as possible; and that all be handled similarly. These precautions will insure that differences noted in performance of animals receiving different levels of protein will be *due* specifically to the level of that nutrient, rather than to some other influence.

The lowest level of protein which provides normal growth and performance is considered the protein requirement under the conditions of that particular experiment. This does not necessarily mean that different animals, under different environmental conditions, will do as well on the same level of protein. Animals, seasons, and facilities vary, as does quality of ration ingredients.

Fortunately, different research teams have studied the nutrient requirements of the same species, conducting their research at several locations, with animals having different inheritance and nutritional history, and prob-

ably with rations composed of a variety of feeds. Similarity in a requirement established under these different conditions indicates the nutritive requirement is relatively *stable* and not greatly influenced by the different circumstances. Wide discrepancies in a requirement established indicate these different conditions do have a marked influence and should be considered in ration formulation.

The technique described above for establishing the requirement of a nutrient for *growth* does not necessarily imply this established level is satisfactory for other functions of the animal, such as reproduction, milk secretion, or wool production (Figure 6-2).

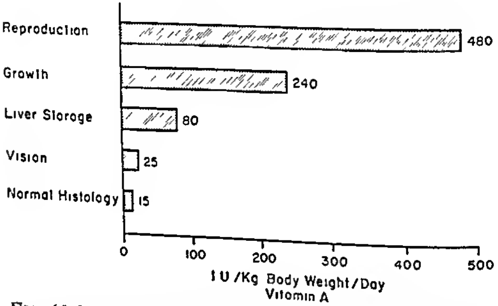


Figure 6-2. The "requirement" for vitamin A in rats. If the criterion for vitamin A adequacy in the ration of a rat is growth, 240 I.U. per kilogram of body weight per day is adequate, according to the above graph. That level, however, will not permit normal reproduction; twice as much is needed. Only 25 I.U. per kilogram of body weight per day apparently would prevent impaired vision, normally considered a symptom of vitamin A deficiency. (*Borden's Review of Nutrition Research*, XVII:2, 1956)

6.2 Safety Factors

Minimum nutrient requirements listed in Table 6-1 for various species presumably were established with healthy, sound animals under good environmental conditions, and with rations adequate in all other nutrients. Requirements given are interpreted as sufficient to prevent deficiency symptoms from occurring, and will usually permit normal health and productivity. This does not mean that these stated levels will permit *maximum* performance in *all* animals under *all* circumstances. Nor does it mean nutrients

Table 6-2. Recommended Nutrient Levels in Non-Ruminant Rations*

	Starting Chickens 0-8 wks.	Swine 25 lbs.	Swine 100 lbs.	Swine 200 lbs.	Calves[3] 75-100 lbs.	Lambs[4] 25 lbs.
Crude protein, per cent	20.00	18.00	14.00	12.00	20.00	22.50
Calcium, per cent	1-1.50	0.80	0.65	0.65	0.60	0.85
Phosphorus, per cent	0.6-0.75	0.60	0.50	0.5	0.50	0.70
Salt, iodized, per cent	0.50	0.50	0.50	0.50	1.00	0.50
Potassium, per cent	*[1]	*	*	*	*	-[1]
Manganese, mg./lb.	*	*	*	*	*	-
Iodine, mg./lb.	*	*	*	*	*	-
Magnesium, mg./lb.	*	*	*	*	*	-
Vitamin A, U./lb.	4000.00	2000.00	3280.00	3330.00	5000	-
Vitamin D, U./lb.[2]	300.00	400.00	300.00	300.00	400	-
Thiamin, mg./lb.	*	*	*	*	*	-
Riboflavin, mg./lb.	2.00	2.40	2.40	2.40	*	-
Niacin, mg./lb.	20.00	20.00	16.00	16.00	*	-
Pantothenic acid, mg./lb.	5.60	8.00	6.00	5.50	*	-
Choline, mg./lb.	700.00	450.00	400.00	300.00	*	-
Pyridoxine, mg./lb.	*	*	*	*	*	-
Vitamin B_{12}, mg./lb.	5.00	12.50	8.00	8.00	*	-
Additives (when used):						
Antibiotics, mg./lb.	1-5.00	25.00	10.00	10.00	10.00	-
Arsenical (3-nitrol), per cent		—	0.0025	0.0025		
Antioxidant (100 BHT), per cent	0.01	0.006	0.01	0.01	0.01	-

*Compiled by the author and colleagues.

[1] An asterisk indicates natural rations usually do not need supplemental quantities. A void indicates lack of sufficient information.

[2] Vitamin D_3 is for chickens; vitamin D_2 for swine and calves.

[3] Figures given are for a calf starter which would supplement whole milk or a highly fortified "milk replacer."

[4] The figures given, except salt, are calculated by converting approximate nutrient content of ewe's milk to an air dry basis.

present when the ration is mixed will maintain their potency until the ration is fed *Safety factors* are added to minimum requirements to allow for such items Table 6 2 provides some ***recommended*** nutrient levels for non-ruminants, *including* reasonable safety factors suitable for most production situations

Lack of complete knowledge of nutrient requirements is the first limiting factor in using the minimum requirement figures in Table 6-1 for ration formulation Knowledge is sparse and sometimes completely lacking on the needs of animals for certain nutrients This may be because deficiencies of these nutrients have never been suspected with normal rations, and research on requirements, therefore, is not considered worthwhile

Extra levels of relatively *unstable nutrients* are often added to rations Farm grown feeds lose some potency of vitamin A and other vitamins during curing and storage (Table 6 3) Vitamins in other feeds or added in synthetic form, and some feed additives, can be destroyed during processing and storage Such destruction is promoted by sunlight, high concentrations of minerals, moisture, high temperature, pelleting, and prolonged storage Destruction is proportionally greater when large quantities have been added, such as in baby pig diets Antioxidants and stabilizers are often added to deter vitamin destruction Also, vitamin manufacturers have developed more stable products than were formerly available Responsible manufacturers and feeders are careful that inventories of feed on hand do not pile up especially during the summer

Table 6 3 Approximate Vitamin A Content of Yellow Corn and Alfalfa (International units per pound)

Corn[1]		Alfalfa[2]	
New	1,720	Growing	173,000
1 year old	1,330	Sun-cured	18,000
2 year old	869	Cured in rainy weather	4,500
3 year old	809	Barn-dried	21,000
4 year old	821		

[1]Harold L Wilcke personal communication Feb 23 1955
[2]Calculations from data in F B Morrison and Associates *Feeds and Feeding* 22nd ed third printing 1959 By permission of The Morrison Publishing Company Clinton Iowa

A safety factor may be added because of the danger of incomplete mixing of micronutrients [1] A baby pig eats less than a pound of feed per day A three day old chick consumes less than a tenth of a pound Unless mixing is almost perfect, thus small portion of feed may not contain sufficient quantities of all nutrients

[1] Micronutrients—nutrients added to feeds in minute quantities such as vitamins trace minerals and amino acids

Figure 6-3. It may be worthwhile to increase levels of critical nutrients the first few days after feeder pigs arrive, especially if they appear thin and tired out (*Successful Farming*)

Hot weather often reduces feed consumption, so less of each nutrient is consumed each day. A high safety factor should be considered, therefore, for those nutrients whose requirements are not necessarily proportional to feed intake and may be needed on a daily basis.

Extra levels of such critical nutrients as vitamins, trace minerals, and protein are often included in rations fed animals with a poor nutritional history or which have been subjected to disease and other stresses. Runt pigs, feeder pigs shipped a great distance, and orphan lambs are examples. These animals are more susceptible to disease and infections, so a high safety factor in critical nutrients, antibiotics, and other such additives for these animals is usually justifiable (Figure 6-3).

6.3 Feeds

Few roughages are used in rations for non-ruminants. Silage and ground hay are often fed to sows and sometimes rations for poultry and growing swine contain small proportions of dehydrated alfalfa meal as a source of critical vitamins, but *concentrates* comprise the major portion of non-ruminant rations. Nutrient analyses of feeds most commonly used are in Table 6-4.

Grains are fed for the energy they contain. Corn and grain sorghum, the most popular grains, are highly digestible because they contain high levels of starch (NFE) and very little fiber. They are relatively low in protein, in relation to the requirements of non-ruminants, and the protein they contain is low in certain amino acids. Corn is the only grain that supplies vitamin A potency.

Table 6-4 Approximate Analyses of Feeds Commonly Used in Non Ruminant Rations*

Feeds	Protein, %	Fat, %	Fiber, %	Calcium, %	Phosphorus, %	Vit A, I U /lb	Riboflavin (Milligrams per pound)	Pantothenic acid (Milligrams per pound)	Niacin (Milligrams per pound)	Choline (Milligrams per pound)
Alfalfa meal (dehydrated)	17 0	2 0	25 0	1 50	0 20	100,000	7 0	14 0	14 0	400
Alfalfa meal (sun-cured)	13 0	1 5	33 0	1 20	0 20	10,000	5 0	10 0	9 0	300
Barley	11 5	2 0	6 0	0 05	0 30	—	0 7	3 0	24 0	450
Beet pulp (dried)	8 0	0 5	21 0	0 60	0 05	—	0 3	0 5	6 0	370
Bonemeal	6 0	—	—	28 00	13 00	—	0 4	0 8	2 0	—
Brewers dry yeast	45 0	1 0	2 7	0 10	1 40	—	15 0	50 0	203 0	1750
Buttermilk (dried)	32 0	5 0	—	1 30	0 90	—	12 0	19 0	7 5	500
Corn (yellow)	8 8	3 8	2 5	0 01	0 25	1,000	0 5	2 4	9 8	200
Corn and cob meal (yellow)	7 0	3 0	8 0	0 01	0 25	800	0 4	2 0	7 2	160
Cottonseed meal (solvent)	41 0	1 5	13 0	0 15	1 25	—	2 0	6 5	20 0	1200
Dicalcium phosphate	—	—	—	26 00	20 00	—	—	—	—	—
Distillers dried solubles (corn)	27 0	8 0	4 0	0 35	1 37	1 000	8 0	10 0	54 0	2200

Fat, animal	–	100.0	–	–	–	–	–	–	–	–
Fish meal (menhaden)	60.0	7.5	1.0	5.00	3.00	–	2.0	4.0	25.0	1500
Fish solubles (50 per cent solids)	32.0	4.0	–	0.10	0.50	–	6.0	16.0	100.0	1300
Grain Sorghum	11.0	2.5	2.5	0.02	0.33	–	0.4	4.0	13.0	220
Hominy feed (yellow)	10.0	5.0	6.0	0.02	0.50	–	1.0	4.5	20.0	460
Limestone	–	–	–	39.00	–	–	–	–	–	–
Linseed meal (solvent)	34.0	0.5	9.0	0.35	0.75	–	1.3	6.4	20.0	800
Meat and bone scrap	50.0	9.0	2.5	10.00	5.00	–	1.5	1.8	21.0	750
Molasses, cane (blackstrap)	3.0	–	–	0.50	0.05	–	1.0	17.0	20.0	300
Oats	12.0	3.5	12.0	0.10	0.36	–	0.4	3.5	5.0	425
Oat groats	15.5	5.5	2.5	0.05	0.45	–	0.5	5.6	3.7	550
Peanut meal (solvent)	47.0	1.0	13.0	0.20	0.60	–	2.4	24.0	77.5	800
Skim milk (dried)	34.0	0.5	–	1.25	1.00	–	9.0	15.0	5.0	500
Soybean meal (solvent, dehulled)	50.0	0.5	3.0	0.20	0.60	–	1.2	6.0	9.5	1300
Soybean meal (solvent)	44.0	0.5	7.0	0.25	0.65	–	1.3	6.0	12.0	1200
Tankage	60.0	8.0	3.0	6.00	3.00	–	1.0	1.0	18.0	1000
Wheat (hard)	15.0	1.8	3.0	0.05	0.40	–	0.6	4.5	24.0	350
Wheat bran	15.0	3.5	11.0	0.10	1.20	–	1.0	12.0	65.0	460
Wheat flour midds (gray shorts)	17.0	3.5	6.0	0.05	0.70	–	0.6	7.0	40.0	450
Whey (dried whole cheese)	12.0	0.5	–	0.80	0.70	–	12.0	20.0	5.0	900

[a]Adapted from *Iowa Agr. Exp Sta. Mimeo, A H.* 778, Feb. 1959.

Wheat is a potent energy feed for hogs and other non-ruminants but is usually too expensive for livestock Barley and oats, being higher in fiber and lower in digestible energy, are less valuable Because of the higher digestible energy content and usually higher yield per acre, corn or gain sorghum are nearly always a cheaper energy source than oats or barley Since they are more concentrated energy sources, a pig can consume more energy and gain faster

Certain low fiber grain products, such as oat groats, wheat middlings, and wheat shorts, are used Oat groats—kernels will hulls removed—are low in fiber, palatable, and high in digestible energy The cost of hulling, and the fact that hulls removed have little value, restricts the use of oat groats to pig starters where palatability and high energy are so important

Animal fat is a potent energy source Each pound of digestible fat supplies two and one quarter or more times as much usable energy as a pound of digestible carbohydrate Fats are also used in feeds to reduce dustiness, improve appearance of mixed feed, and provide lubrication during pelleting Molasses is a good energy source, but since large proportions are difficult to use in rations, it is normally used at low levels to increase palatability and promote feed consumption

Soybean, cottonseed, linseed, and peanut meal—all by-products of oil extraction—are the main plant sources of supplemental protein Their economy and use in rations is greatest in the areas where produced A shift from mechanical to solvent extraction of the oil has resulted in meal products that are lower in fat, slightly higher in protein, and mueh more uniform in quality than formerly This shift occurred earliest and most rapidly in soybean processing Soybean meal, because of (1) excellent palatability, (2) uniform processing, (3) high content of the critical amino acid, lysine, and (4) because soybeans are grown and processed in the same area where most hogs are grown, is the most popular supplemental protein source in non ruminant rations Solvent processed soybean meal contains 44 to 50 per cent protein, depending on whether or not hulls are added back following extraction and toasting

By products of the meat industry—meat and bone scrap, tankage, liver meal, and blood meal—and fish by products are potent sources of supplemental protein These products supply some of the amino acids, minerals, and vitamins that are relatively low in the protein of grain and plant oil-meals This fact was more important in the 1930's before supplemental sources of these micronutrients became commercially available

Dried skim milk, brewers dry yeast, fish solubles, whey, and some other feed ingredients supply supplemental protein and are valuable in non-ruminant rations for additional reasons These products are especially high in certain B vitamins and also help supply critical amino acids Unknown growth factors—items apparently present but not identified—have been reported in some of these feeds

Quantity of protein doesn't disclose the real value of a protein source. Level of specific amino acids, as well as processing techniques which might influence the digestibility and availability of these amino acids, are important. Purchasers of protein ingredients use certain laboratory tests to check processing methods and protein quality before accepting delivery.

Mineral supplements high in calcium and phosphorus include bonemeal, dicalcium phosphate, limestone (calcium only), and others. Recent research has shown that phosphorus from dicalcium phosphate or bonemeal is more "available" to non-ruminants than the phosphorus in colloidal phosphate. Salt supplies the necessary sodium, and trace minerals are available individually or in mixtures.

Though whey and some other natural feeds are high in certain vitamins, synthetic vitamins sometimes may be most economical. Purchasers of vitamin premixes or other feed additives should check the potency and stability of the product as well as the cost per unit.

Mixed commercial supplements, to be fed with home-grown grains, vary greatly in price, ingredients, quality, and nutritional value. Except by actual feeding trials it is difficult to appraise accurately the value of such supplements, but Table 6-5 illustrates that wide difference in value might exist.

Table 6-5. Performance of Pigs on Three Different Supplements*

	Supplement		
	A	B	C
Av. daily gain	1.58	1.63	1.87
Age at 200# (days)	159	155	142
Corn per 100 lbs. gain	279	261	255
Supp. per 100 lbs. gain	55	44	39
Calculated value of supp./ton			
Corn at 2¢/lb.	$ 80	$117	$136
Corn at 3¢/lb.	80	125	149
Corn at 2¢/lb.	100	142	164
Corn at 3¢/lb.	100	150	176

*Iowa Agr. Exp. Sta. unpublished data and D. C. Acker *et al.*

Supplement A in the above demonstration contained only soybean meal, dehydrated alfalfa meal, and meat and bone scrap. Supplement B was soybean meal with vitamins A and D added. The third supplement, Supplement C, contained a complex mixture of soybean meal, meat and bone scrap, blood meal, condensed fish solubles, dried whey, and brewer's dry yeast. High levels of the vitamins considered low in natural ingredients, and a mixture of four antibiotics, were added to this third supplement.

Pigs receiving Supplements B and C not only gained faster, but also more efficiently. They used less corn and less supplement per 100 pounds of gain. The values for Supplements B and C in the above table were calcu-

lated based on Supplement A at $80 or $100 per ton and corn at two or three cents per pound

It is apparent from the above demonstration that the value of a supplement is determined by its composition and *also* by the price of grain When corn was figured at three cents per pound instead of two cents, the relative values of Supplements B and C were even higher, compared to that of Supplement A, because the corn saved was worth more No credit was given in the calculations for the shorter finishing period resulting from the use of Supplements B and C, and the consequent reduction of labor, risk, and interest on investment.

6 4 Formulating Rations

Protein is usually the criterion for determining the proportion of major ration ingredients Protein is the most expensive of the macronutrients (carbohydrate, fat, and protein) and is one which cannot be replaced, as carbobydrate can be replaced by fat to provide energy Enough high protein ingredients must be used to supply ample protein, but excess protein is of no additional value and is expensive

When corn or grain sorghum is combined with a "complete" supplement (one which supplies protein, minerals, vitamins, and additives), a simple algebraic procedure discloses the correct and most economical mixture that will meet the animals' requirements (Figure 6-4, Example A) This same technique can be used for more complex mixtures where a certain ratio of grains is to be used in the ration or where predetermined quantities of certain feeds are to be incorporated (Figure 6-4, Examples B and C) These illustrations indicate the precision that is possible with the use of simple algebra

A complete and thorough discussion of ration formulation for non ruminants cannot be presented here, though Figure 6-5 does illustrate a complete ration formulated for growing pigs

Palatability, cost, mechanical condition, and bulkiness of ingredients are *often as important* in ration formulation as nutrient content There is a limit to the amount of molasses, fish solubles, or animal fat which other ingredients will absorb An excess will cause the feed to cake or "set up" in storage or in a feeder Pellets made from the mixture will crumble Also feeds that are too dusty or otherwise unpalatable will not be consumed well

6.5 Feed Consumption

Maximum feed consumption is usually desired for young animals—chicks, pigs, calves, and lambs—so they will be sure to consume enough energy yielding nutrients and nutrients to supply their other needs (Figure

<u>Example A</u> (Feeder wants a 14 per cent protein ration)

x = lbs corn, 8.8% protein
y = lbs. "complete" swine supplement, 35% protein.

$$x + y = 100 \text{ lbs ration}$$
$$088x + .35y = 14 \text{ lbs. protein}$$

Now expand the equations to eliminate x or y

$$\begin{aligned} 88x + 350y &= 14{,}000 \\ \underline{88x + 88y} &= \underline{8{,}800} \\ 262y &= 5{,}200 \\ y &= 19\ 8 = \text{lbs supplement} \\ x = 100 - y &= 80\ 2 = \text{lbs. corn} \end{aligned}$$

Now check the work

80 2 lbs corn	x 8 8% protein =	7 06
19.8 lbs supplement	x 35 0% protein =	6 93
		13 99 lbs protein

<u>Example B</u> (Feeder wants to use 1/2 barley and 1/2 corn for the grain portion of the ration)

x = lbs grain, 10 15% protein (av. of corn and barley).
y = lbs "complete" swine supplement, 35% protein

$$x + y = 100 \text{ lbs ration.}$$
$$1015x + .35y = 14 \text{ lbs protein}$$

<u>You</u> carry it from here --

Example C (Feeder wants to use 10 lbs wheat per 100 lbs of ration).

x = lbs. corn, 8 8% protein
y = lbs "complete" swine supplement, 35% protein.

The <u>10</u> lbs. of wheat will supply <u>1 5</u> lbs protein, so

$$x + y = 90$$
$$.088x + 35y = 12.5$$

<u>You</u> carry it from here --

Figure 6-4. Using algebra to establish the correct proportions of ingredients in 14 per cent protein swine rations

6-6). Broilers and hogs being fed for market are usually fed *ad libitum*, that is, feed is available to them at all times Sugar, molasses, saccharin, or certain flavors are sometimes added to encourage increased feed intake

The normal daily feed consumption for non-ruminants of various weights given in Table 6-6 indicates consumption on full feed ranges from approximately 2 to 13 per cent of body weight. Feed consumption in swine and poultry, expressed as a percentage of body weight, declines as the animal grows because volume consumed does not increase as fast as body weight. In calves and lambs, however, feed consumption increases faster than body weight because of the development of the rumen and other stomach com-

RATION FORMULATION

Class of livestock Swine Age 5 weeks Weight 25 lbs By D.C.A. Date Jan. 5, 1962

Ingredients	Total	Calculated Analysis										
		Protein lb.	Fat lb.	Fiber lb.	Ca lb.	P lb.	Vit. A I.U.	Vit. D I.U.	Ribo. mg.	P.A. mg.	Niacin mg.	Choline mg.
Corn (yellow)	71.2	6.27	2.71	1.78	.007	.178	71,200		35.6	170.9	697.8	14,240
Soybean meal (solv.)	20.5	9.02	.10	1.43	.051	.133			26.6	123.0	246.0	24,600
Meat & bone scrap	2.0	1.00	.18	.05	.200	.100			3.0	3.6	42.0	1,500
Fish meal (menhaden)	1.5	.90	.11	.01	.075	.045			3.0	6.0	37.5	2,250
Fish solubles (50% solids)	1.0	.32	.04		.001	.005			6.0	16.0	100.0	1,300
Skim milk, dried	1.5	.51	.75		.019	.015			13.5	22.5	7.5	750
Limestone	0.7				.273							
Dicalcium phosphate	0.7				.182	.126						
Salt	0.5											
Trace mineral premix	0.1											
Vitamin A premix	0.04						130,000					
Irradiated yeast	0.01							40,000				
B vitamin premix	0.10								200.0	400.0	900.0	1000
Antibiotic premix	0.15											
Totals	100.0	18.02	3.89	3.27	.808	.602	201,200	40,000	287.7	742.0	2030.8	45,640
Calculated Analysis		18%	3.9%	3.3%	0.8%	0.6%	2012/lb.	400/lb.	2.9/lb.	7.4/lb.	20/lb.	456/lb.
Nutritive Requirements		18%			0.8%	0.6%	2000/lb.	400/lb.	2.4/lb.	6/lb.	20/lb.	450/lb.

Figure 6-5. A completed ration formulation sheet showing ingredients, quantities of nutrients supplied by each ingredient, and calculated analysis. The ration is a complete ration for growing pigs.

Table 6-6. Approximate Daily Feed Consumption and Gain of Non-Ruminants*

Species and age or weight	Air - dry feed		Gain
	Pounds	Per cent of body weight	
Swine:			
25 lbs.	2.00	8.00	0.80
50 lbs.	3.20	6.40	11.20
100 lbs.	5.30	5.30	1.60
150 lbs.	6.80	4.53	1.70
200 lbs.	7.50	3.75	1.90
250 lbs.	8.30	3.32	1.90
Pregnant gilts, 300 lbs.	6.00	2.00	1.00
Pregnant sows, 500 lbs.	7.50	1.50	0.70
Lactating gilts, 350 lbs.	11.00	3.14	-
Lactating sows, 450 lbs.	12.50	2.78	-
Mature boars, 500 lbs.	7.50	1.50	-
Poultry:			
0.5 lb. broiler	.065	13.00	0.04
2.5 lb. broiler	.190	7.60	0.045
4.0 lb. layer	.241	6.00	-
Calves:			
50 lbs.	0.90	1.80	0.50
100 lbs.	2.00	2.00	0.90
150 lbs.	4.00	2.67	1.40
200 lbs.	6.00	3.00	1.60
Lambs:			
15 lbs.	0.25 (plus milk)	1.60	0.25

*Adapted from National Research Council publications and other sources.

partments, and because the animals consume increasing proportions of less efficiently digested roughages.

Feeds vary greatly in palatability. New corn is preferred to old corn that has been stored several years. Corn is more palatable to pigs than grain sorghum, because of the harder seed coat and tannic acid in some grain sorghum. Corn is also more palatable than most small grains that have a coarse, fibrous hull. Cracked, rolled, or crushed grain is usually more desired than whole kernels but must not be ground too fine.

Soybean meal is the most palatable of common protein feeds. Complete supplements sold in the Midwest are usually composed largely of soybean meal because of its economy, availability, and good, uniform quality. When such a supplement is offered free choice, along with old corn or other grain, pigs often overeat on supplement.

Many valuable ingredients are relatively unpalatable, so must be used in limited quantities or in combination with especially well-liked feeds. Tankage or meat and bone scrap are relatively unpalatable, especially for young animals. In Iowa tests, feed consumption decreased when more than

Figure 6 6 To permit maximum feed consumption ample feeder space must be provided for young livestock (Iowa State University and Walnut Grove Products Co)

five per cent meat and bone scrap was included in a complete ration for growing pigs Milk by-products are unpalatable when fed alone but seem to improve palatability of supplements or complete rations

Excess amounts of minerals are unpalatable to all farm animals Alfalfa meal, ground oats, distillers solubles, and certain mill by-products are not especially well liked, especially by very young animals

Pelleting improves palatability and feed consumption The benefit is the greatest when relatively unpalatable ingredients are used, but is considered worthwhile in almost any situation where maximum feed consumption is desired Crumbles, which are usually broken pellets, are well liked by non ruminants unless they include too much fine material

Availability of feed that is clean and fresh helps feed intake Animals prefer freshly ground or mixed rations Self feeders should be closely adjusted to prevent feed accumulation in the trough where it may become stale or wet Poultrymen often stir the feed in open feeders several times daily, and some let the feeders remain empty for an hour or two each day Then, when fresh feed is supplied, the birds really eat

More than 300 feet between feed and water will reduce feed consumption and pig gains, according to South Dakota research This is obviously important for other species as well, especially in adverse weather

Animals eat less in extremely hot weather, an unfortunate consequence since the need for certain vitamins is actually increased by high temperature If animals consume less total ration, they are consuming less B vitamins And these same B vitamins are recognized as being important for maintaining normal feed intake So many poultrymen in hotter climates sprinkle a high potency "top feed" in the feeders several times each week during prolonged hot weather This top feed usually contains ten or more times the normal level of vitamins and extra high levels of trace minerals It stimulates consumption and helps prevent production slumps

Artificial cooling, by fan or water mist, may be worthwhile to maintain feed consumption and utilization during the summer months.

Psychological aspects of feed consumption and competition among animals in a given pen are of current interest.

6.6 Least-Cost Rations

Since protein is the most expensive macronutrient, the prices of protein sources have a great influence on the cost of a ration per pound, and therefore on the cost of weight grain. During seasons when protein sources such as oilmeals are relatively cheap, it is usually advantageous to feed as high a protein level as will be beneficial to animal performance. In such cases, the most rapid gains will be the cheapest gains because the animals are maintained fewer days and a larger proportion of consumed nutrients is used for growth.

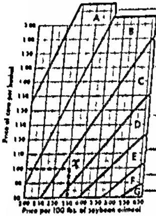
If, however, oilmeals increase in price and/or grain decreases in price, it may be practical to formulate a lower protein ration containing less oilmeal. The slower gains that would result from this lower protein ration mean that relatively more of the feed consumed is being used for maintenance rather than growth, so more pounds of feed are consumed per pound of gain. This is practical, though, if the low protein ration is enough cheaper so that cost of gain is less.

Least-cost rations are those which will produce gains at the lowest possible feed costs. Relative prices of corn (or other major energy-yielding feed) and the protein source are considered when these rations are calculated. Figure 6-7 illustrates least-cost rations for various weights of hogs, depending on prices of corn and soybean meal. These graphs were compiled from data on large numbers of hogs under good management conditions at the Iowa Agricultural Experiment Station. This does not mean the graphs can be applied directly to all hog-producing situations. Hogs subjected to severe stresses would be expected to do relatively poorly on the low protein rations, more poorly than the low protein-fed hogs used as a basis for these graphs.

The least-cost ration principle is sound and least-cost rations have been developed for chickens and turkeys, as well as for swine. The principle is used in feeding programs for other species as well, even though complete least-cost systems have not been calculated. Certainly feeders will watch ingredient costs closely and will make desirable shifts in formulation in order to produce meat most economically.

GRAPH 1

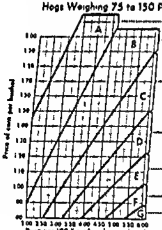
Hogs Weighing 50 to 75 Pounds



	Percent Protein in Ration	(8.8%) Ground Yellow Corn	(44%) Solvent Soybean Oil Meal	Vitamin-Mineral-Additive Premix 1/
		Mixing Instructions (1 Ton Basis)		
A	21.0	1180	720	100
B	17.9	1360	540	100
C	16.0	1465	435	100
D	14.8	1535	365	100
E	13.9	1585	315	100
F	13.2	1625	275	100
G	12.7	1655	255	100

GRAPH 2

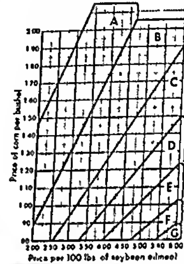
Hogs Weighing 75 to 150 Pounds



	Percent Protein in Ration	(8.8%) Ground Yellow Corn	(44%) Solvent Soybean Oil Meal	Vitamin-Mineral-Additive Premix 1/
A	13.9	1615	310	75
B	12.2	1715	210	75
C	11.5	1765	160	75
D	10.8	1795	130	75
E	10.4	1815	110	75
F	10.1	1835	90	75
G	10.0	1840	85	75

GRAPH 3

Hogs Weighing 150 to 200 Pounds



	Percent Protein in Ration	(8.8%) Ground Yellow Corn	(44%) Solvent Soybean Oil Meal	Vitamin-Mineral-Additive Premix 1/
		Mixing Instructions (1 Ton Basis)		
A	11.8	1765	185	50
B	10.7	1830	120	50
C	10.1	1865	85	50
D	9.8	1880	70	50
E	9.5	1900	50	50
F	9.4	1905	45	50
G	9.3	1910	40	50

1/ Vitamin-Mineral-Additive Premix for "Least-Cost" Rations

Ingredients:	Amount (lb.)	Premix Calculated Analysis:	
Calcium Carbonate (38% Ca)	15.0	Calcium, %	13.6
Dicalcium Phosphate (26% Ca. 18% P)	30.0	Phosphorus, %	5.7
Salt (Iodized)	10.0	Vitamin D2, I.U./lb.	6000.0
Trace Mineral Premix (Swine)	2.0	Riboflavin, mg./lb.	24.0
Copper Sulfate (25% Copper)	2.0	Calcium Pantothenate, mg./lb.	60.0
3-Nitro (10% concentrate)	0.75	Niacin, mg./lb.	144.0
Antioxidant (25% BHT concentrate)	0.10	Vitamin B_{12}, mcg /lb.	100.0
Vitamins:		3-Nitro, %	0.075
Vitamin D2, I.U.	600,000	BHT, %	0.025
Riboflavin, grams	2.4		
Calcium Pantothenate, grams	6.0		
Niacin, grams	14.0		
Vitamin B12, milligrams	10.0		
Premix Carrier (Corn, Soybean Meal or Midds.)	(remainder)		
Total	100.0 lb.		

Figure 6-7. A calculated "Least-Cost" system of formulating swine rations using corn, soybean meal, and a vitamin-mineral-additive premix. (*Iowa Agr. Exp. Sta. Mimeo. A.H. 778*)

7

RUMINANT NUTRITION

Ruminant nutrition is centered on roughage utilization. Cattle and sbeep convert grass and other forage into marketable products—meat, milk, or wool. Ruminants are less efficient in the conversion of concentrates into meat than are swine and poultry, but are much more efficient tban non-ruminants in utilization of roughages because of their unique digestive system and the population of microorganisms it contains.

About 70 per cent of the agricultural land in the U.S. is in permanent pasture, or timber than can also be used for grazing. Such land varies in productivity but the total annual yield of forage is tremendous. Further, it is estimated that about 35 per cent of the tilled or "crop" land grows forage —temporary pasture or forage for hay or silage—each year. In addition much rougbage is produced along with grains and other concentrates. Corn stalks and cobs are roughage by-products of corn production; straw remains when small grains or beans are harvested; and beet tops and cottonseed hulls are also by-product roughages available for ruminant consumption. It is easy to visualize, therefore, that a very large proportion of the energy stored by photosynthesis in plants is stored in what nutritionists call roughage, efficiently utilized *only* by ruminants.

Concentrates are used when needed to supplement the roughages, for more rapid growth, quicker marketing, or higher quality carcasses, or for maximum milk production during lactation. Dairy cows in high production consume large proportions of concentrate, but the concentrate mixture is formulated according to the quality and amount of roughage fed. Lambs fed for slaughter often receive 50 or 60 per cent concentrate, so that their daily energy intake will be high enough to promote fattening at desired weights. The same is true in cattle fed for slaughter when the goal is the choice or prime grade.

7.1 Nutrient Requirements

Fewer nutrients are required in ruminant rations than in rations of non-ruminants. B vitamins need not be present because ruminant microorganisms can synthesize adequate quantities from elements in the ration. The

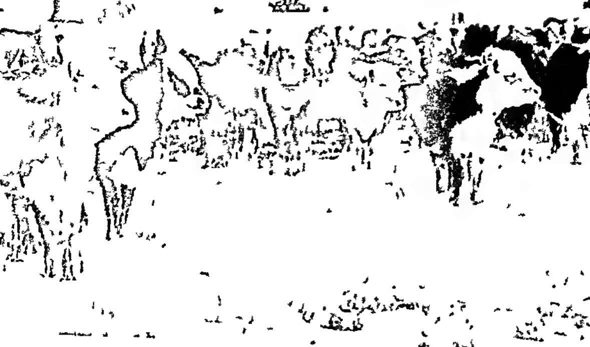


Figure 7 1 Calves being "wintered" on stacked alfalfa in western South Dakota (*Successful Farming* Magazine)

same is true for individual amino acids, providing there is enough total protein in the ration Carbohydrates and fats both supply energy, so formulation of nutritionally adequate rations usually involves consideration of only protein energy, minerals, and vitamins A and D

Requirements for cattle and sheep have commonly been stated on a "per day" basis (Table 7 1) This is because nutrient intake of grazing animals has been controlled by the *volume* of roughage dry matter they could consume *per day* and also because ruminants fed in dry lot have most commonly been *hand fed* roughage and concentrate separately once or twice per day

However, because of the current trend toward the use of complete rations for dairy cows, beef cattle, and lambs in dry lot, interest in stating nutritive requirements as a percentage of the ration has increased (Table 7-2)

Note that the requirements listed in Tables 7-1 and 7-2 are dependent not only on animal weight, but also on the *job to be done*, that is, maintenance through the winter, fattening for slaughter, growth of dairy heifers, pregnancy, or lactation

Requirements given are considered satisfactory for good performance *under average conditions* Maximum performance is not guaranteed and no margins of safety are included in the requirements One must consider, therefore, such things as previous nutritional history, environmental stresses, palatability of feeds, and stability of nutrients when formulating ruminant rations

Requirements given in Table 7 2, stated as a proportion of the ration, provide opportunity to compare requirements at different stages in the

life cycle and between species. Additional requirements are given in the references cited in the footnote at the bottom of the table.

Digestibility is considered in both energy and protein requirements because feeds in ruminant rations *vary so greatly* in digestibility. For example, the digestion coefficient[1] for the N.F.E. in corn is about 93 per cent, while the digestion coefficient for the N.F.E. in alfalfa hay is only about 50 per cent. Further and more striking illustrations of differences which exist in digestible energy and digestible protein values of ruminant feeds are in Table 7-3.

Digestible energy requirements are stated two ways, as TDN and as therms. TDN has been used for over half a century as an indicator of the digestible energy that a feed supplies. The letters stand for the words "Total Digestible Nutrients," and so the term is a *misnomer* in the middle of the twentieth century when we know that there are six different classes of nutrients and that three classes (minerals, vitamins, and water) do *not* supply energy. We must realize, however, that the term was coined late in the nineteenth century when the term "nutrient" implied only compounds which provide energy. TDN is calculated by adding digestible fat $\times$ 2.25 (since fat is relatively more potent as an energy source) to digestible carbohydrate (N.F.E. and fiber) and digestible protein.

The term TDN has been satisfactory (though not perfect) as an index of the energy value of feeds and therefore its use has persisted in nutrition, although it does provide some confusion for each new student of nutrition. The author, therefore, prefers the use of the term "digestible energy," or else the term TDN, forgetting the words the letters originally represented.

Since TDN is a calculated value, and includes the factor 2.25 for digestible fat, any calculated TDN value is not a tangible, visible quantity, but rather is *merely* an *index* to the digestible energy required by the animal or contained in the feed.

A therm, however, is a tangible quantity with physical meaning. It is the amount of heat required to raise the temperature of 1,000 kilograms of water 1° Centigrade, or approximately 1,000 pounds 4° Fahrenheit. It is equivalent to 1,000 Calories.

Nutrients for which requirements are not stated are generally considered to be adequate in most typical rations. Exceptions do exist, however, such as the lack of iodine in feeds grown in certain North Central states.

Salt is normally provided free choice in loose form, or may be added to the concentrate mix or complete ration at about 0.5 per cent.

Though corn is the only grain with considerable vitamin A potency, nearly all good quality roughages contain high levels of this vitamin. Re-

[1] Digestion coefficient—the percentage of a nutrient that is apparently digested and absorbed. The amount apparently absorbed is calculated by subtracting the amount of the nutrient in the feces from the amount of the nutrient in the feed consumed. Quantities of the nutrients in the feed and feces are determined by chemical analysis.

Table 7 1. Daily Nutrient Requirements of Certain Ruminants*

Av daily gain, lbs	Daily feed per animal,[1] lbs	Daily nutrients per animal							
		Total protein, lbs	Digestible protein, lbs	Digestible energy		Calcium, gms	Phosphorus, gms	Vit A, I U [4]	Vit D, I U [5]
				TDN[2], lbs	Therms[3]				
600-lb fattening calves finished as short yearlings									
2 4	16 0	1 8	1 3	10 9	22 0	20 0	17 0	4,000	—
800-lb fattening yearling cattle									
2 8	22 0	2 2	1 6	14 3	29 0	20 0	20 0	5,600	—
Wintering 500-lb weanling calves									
1 0	13 0	1 3	0 6	7 0	14 0	13 0	10 0	3,600	—
Wintering 1,000-lb mature pregnant beef cows									
0 4	18 0	1 4	0 8	9 0	18 0	13 0	12 0	16,000	—
200-lb growing dairy heifers									
1 8	0 0	0 94	0 0	4 0	8 1	13 0	10 0	3,200	600
1,000-lb dairy cows producing 40 lbs of 5% milk									
--	30 0	4 25	2 6	21 8	44 1	46 0	30 0	16,000	—

·lb. dairy cows producing 50 lbs. of 4% milk 40.0	4.82	2.95	24.2	49.1	60.0	45.0	19,200	—
·lb. dairy cows producing 60 lbs. of 3.5% milk 40.0	5.47	3.32	27.4	55.6	71.0	53.0	22,400	—
-lb. dairy cows, dry, last 2 months of pregnancy 28.0	2.71	1.44	16.0	32.2	19.5	18.5	36,000	—
lb. ewes, not lactating and first 15 weeks of gestation 3.0	0.23	0.13	1.5	3.0	3.3	2.6	1,156	300
lb. ewes, last 6 weeks of gestation 4.6	0.36	0.20	2.4	4.8	4.6	3.5	3,240	350
lb. ewes, first 8 to 10 weeks of lactation 8 5.0	0.42	0.23	2.9	5.9	6.5	4.8	2,775	300
b. fattening lambs 3.4	0.35	0.19	2.1	4.2	3.0	2.7	771	200

ɔted from National Research Council Publications, *Nutrient Requirements of Beef Cattle*, 1958; *Nutrient Requirements of Dairy Cattle*, ; and *Nutrient Requirements of Sheep*, 1957

e daily feed per animal is based on a ration containing 90 per cent dry matter, rations containing silage or other wet feed would need to be sted according to the percentage of dry matter they contain.

l is the sum of digestible fat x 2.25, digestible carbohydrate (NFE and fiber), and digestible protein.

erm is the amount of heat required to raise 1,000 kilograms of water 1° Centigrade, or approx. 1,000 lbs. 4° Fahrenheit.

min A computed on the basis that one mg. carotene equals 400 I.U. vitamin A.

min D required by all, but figures are not given where data are inadequate.

Table 7 2. Nutrient Requirements of Certain Ruminants as a Proportion of Air Dry Rations*

Av daily gain, lbs	Daily feed per animal,[1] lbs	Total protein, %	Digestible protein, %	Digestible energy TDN,[2] %	Digestible energy Therms,[3]/lb	Calcium, %	Phosphorus %	Vit A I U /lb [4]	Vit D I U /lb [5]
600-lb fattening calves finished as short yearlings									
2 4	16 0	11 0	8 2	68 0	1 36	0 28	0 23	240	
800-lb fattening yearling cattle									
2 8	22 0	10 0	7 5	65 0	1 30	0 20	0 2	240	–
Wintering 500-lb weanling calves									
1 0	13 0	10 3	6 2	54 0	1 08	0 22	0 17	280	–
Wintering 1,000-lb mature pregnant beef cows									
0 4	18 0	7 5	4 5	50 0	1 0	0 16	0 15	880	–
200-lb growing dairy heifers									
1 6	6 0	15 7	10 0	67 0	1 35	0 48	0 4	520	–
1,000-lb dairy cows producing 40 lbs of 5% milk									
--	36 0	11 0	8 5	60 0	1 21	0 3	0 25	480	–
1,200-lb dairy cows producing 50 lbs of 4% milk									
--	40 0	11 0	6 5	60 0	1 21	0 3	0 25	480	–

,400-lb. dairy cows producing 60 lbs. of 3.5% milk									
-	44.0	11.0	6.5	60.0	1.21	0.3	0.25	480	—
,500-lb. dairy cows, dry, last 2 months of pregnancy									
2.0	28.0	10.0	5.1	57.0	1.15	0.67	0.65	1,300	—
120-lb. ewes, not lactating and first 15 weeks of gestation									
0.07	3.0	7.6	4.2	50.0	1.0	0.24	0.19	385	100
140-lb. ewes, last 6 weeks of gestation									
0.37	4.6	7.7	4.3	52.0	1.1	0.22	0.16	704	76
120-lb. ewes, first 8 to 10 weeks of lactation									
-0.08	5.0	8.3	4.6	58.0	1.2	0.28	0.21	555	60
80-lb. fattening lambs									
0.40	3.4	10.3	5.6	62.0	1.2	0.19	0.17	227	59

*Adapted from National Research Council Publications, *Nutrient Requirements of Beef Cattle*, 1958; *Nutrient Requirements of Dairy Cattle*, 1956, and *Nutrient Requirements of Sheep*, 1957.

[1]Based on air-dry feed containing 90 per cent dry matter.

[2]TDN is the sum of digestible fat x 2.25, digestible carbohydrate (NFE and fiber), and digestible protein.

[3]A therm is the amount of heat required to raise 1,000 kilograms of water 1° Centigrade, or approx. 1,000 lbs. 4° Fahrenheit.

[4]Vitamin A computed on the basis that one mg. carotene equals 400 I.U. vitamin A.

[5]Vitamin D required by all, but figures are not given where data are inadequate.

Table 7 3 Proximate Analyses of Feeds Commonly Used in Ruminant Rations*

Feed	Dry matter, %	Protein, %	Dig protein, %	Digestible energy: TDN [1]%	Digestible energy: Therms[2]/lb	Calcium %	Phosphorus, %	Vit A I U /lb [3]
Dry roughages								
Alfalfa hay	90 5	15 30	10 90	50 70	1 02	1 47	0 24	3,280
Alfalfa meal (dehydrated)	92 7	17 70	12 40	54 40	1 10	1 60	0 28	18,960
Bromegrass hay	88 8	10 40	5 30	55 00	1 00	0 42	0 19	1,400
Clover hay (red)	88 3	12 00	7 20	51 80	1 05	1 28	0 20	2 920
Corn cobs (ground)	90 4	2 30		45 70	0 92	0 11	0 04	--
Mixed hay (good, under 30% legume)	89 2	8 80	4 80	48 80	0 99	0 90	0 19	2,560
Oat straw	89 8	4 10	0 70	44 80	0 90	0 24	0 09	--
Prairie hay (west, midseason)	91 3	8 00	2 00	45 10	0 91	0 33	0 12	3,640
Prairie hay (west, mature)	91 9	4 40	0 90	43 70	0 88	0 38	0 08	1,440
Sorghum fodder (sweet, dry)	88 9	8 20	3 30	52 40	1 08	0 34	0 14	440
Timothy hay	89 0	8 80	3 00	49 10	0 99	0 35	0 14	1,780
Wheat straw	92 8	3 90	0 30	40 60	0 82	0 15	0 07	--
Silages								
Alfalfa (not wilted, no pres)	24 7	4 10	2 80	13 50	0 27	0 35	0 08	8,040
(3 84)[8]	90 0	14 92	9 48	49 14	0 98	1 27	0 29	21,985
Corn (dent, well matured)	27 8	2 30	1 20	18 30	0 37	0 10	0 07	2,320
(3 28)	90 0	7 50	3 91	59 68	1 21	0 33	0 23	7,563
Grass silage (consid legume)	25 0	3 60	2 00	15 50	0 31	0 32	0 12	6,840
(3 52)	90 0	12 67	7 04	54 58	1 09	1 13	0 42	24,076
Oats (molasses added)	32 0	2 70	1 40	18 90	0 34	0 10	0 09	7,080
(2 81)	90 0	7 59	3 93	47 49	0 98	0 28	0 25	19,894
Sudan grass	25 7	2 20	1 50	14 40	0 29	0 11	0 04	1,080
(3 50)	90 0	7 70	5 25	50 40	1 02	0 39	0 14	3,780
Pasture								
Alfalfa	24 4	4 60	3 50	14 80	0 30	0 40	0 08	11,320
(3 69)	90 0	18 97	12 92	54 61	1 11	1 48	0 22	43,884
Alfalfa and bromegrass	22 5	4 80	3 30	13 90	0 28	0 28	0 07	11,800
(4 00)	90 0	19 20	13 20	55 80	1 12	1 12	0 28	47,200
Bermuda grass	25 0	2 80	2 00	15 00	0 30	0 14	0 05	15,400
(3 60)	90 0	10 08	7 20	54 00	1 08	0 50	0 18	55,440
Bluegrass Kentucky	30 2	5 50	4 10	20 70	0 42	0 18	0 13	14,400
(2 98)	90 0	16 39	12 22	61 69	1 25	0 48	0 39	43,200

Bluestem (active growth)	34.1	2.90	1.30	19.50	0.39	0.14	0.05	7,160
(2.64)	90.0	7.66	3.43	51.48	1.03	0.37	0.13	18,902
Bluestem (mature)	50.8	3.60	1.10	27.00	0.55	0.20	0.07	5,000
(1.77)	90.0	6.37	1.95	47.79	0.97	0.35	0.12	8,850
Clover (red)	18.1	3.70	2.80	13.20	0.27	0.41	0.06	8,360
(4.97)	90.0	18.39	13.92	65.60	1.34	2.04	0.30	41,800
Lespedeza	25.0	4.10	2.90	14.20	0.29	0.28	0.07	5,200
(3.60)	90.0	14.76	10.44	51.12	1.04	1.01	0.25	18,720
Wheat	19.8	4.80	3.60	12.70	0.26	0.09	0.08	8,080
(4.55)	90.0	21.84	16.38	57.79	1.18	0.41	0.38	38,784
Concentrates:								
Barley (excl. Pacific coast)	89.4	11.50	9.50	77.70	1.57	0.05	0.30	--
Barley (Pacific coast)	89.8	8.70	6.90	78.80	1.59	0.06	0.33	--
Beet pulp (dried)	90.8	8.00	4.00	68.20	1.38	0.60	0.05	--
Brewers dried grains	92.4	25.90	20.70	66.00	1.33	0.27	0.50	--
Corn and cob meal	86.1	7.00	5.10	73.20	1.48	0.01	0.25	420[4]
Corn (yellow dent, no. 2)	85.0	8.80	6.70	80.10	1.62	0.01	0.25	520
Corn gluten meal	90.7	42.90	36.50	79.90	1.61	0.16	0.40	2,960
Cottonseed meal (solv.)	91.4	41.00	34.50	68.10	1.34	0.15	1.25	--
Flaxseed screenings	91.4	15.80	8.80	58.50	1.18	0.37	0.43	--
Grain sorghum	89.8	11.00	8.90	81.60	1.65	0.02	0.33	--
Linseed meal (solv.)	90.9	34.00	29.00	71.00	1.43	0.35	0.75	--
Molasses (cane)	74.5	3.00	2.70	54.90	1.11	0.50	0.05	--
Oats (excl. Pacific coast)	90.2	12.00	9.40	70.10	1.42	0.10	0.36	--
Peanut meal (solv.)	91.5	47.00	43.10	74.30	1.50	0.20	0.60	--
Rye	89.5	12.60	10.00	76.50	1.55	0.10	0.33	--
Soybean meal (solv.)	89.3	44.00	41.00	77.20	1.56	0.25	0.65	--
Wheat (hard, spring)	90.1	15.00	13.30	80.70	1.63	0.05	0.40	--

*Adapted from National Research Council, *Nutrient Requirements of Beef Cattle*, 1958; and *Iowa Agr. Exp. Sta. Mimeo . A.H. 778*. Feb. 1959; from F. B. Morrison and Associates. *Feeds and Feeding*, 22nd edition, third printing, 1959. By permission of The Morrison Publishing Company, Clinton, Iowa. Missing values were estimated from similar feeds.

[1] TDN is the sum of digestible fat x 2.25, digestible carbohydrate (NFE and fiber), and digestible protein.

[2] A therm is the amount of heat required to raise 1,000 kilograms of water 1° Centigrade, or 1,000 lbs. approx. 4° Fahrenheit.

[3] Assuming one mg. carotene equals 400 I.U. vitamin A.

[4] Vitamin A potency in feeds is provided by carotene and other pigments. Since different species vary in their ability to convert carotene to vitamin A, there may be discrepancies in analysis values of feeds for the various species.

[5] The figure in parentheses is the pounds of wet silage or pasture equivalent to one pound of "dry" silage or pasture (90% dry matter).

quirements given in Tables 7-1 and 7-2 are usually met if animals are pasturing lush grasses or legumes, or are being fed considerable silage or green, leafy hay Deficiencies of vitamin A occur during periods of prolonged drouth, when grass turns dormant, or when animals in dry lot receive only straw or weathered hay and grain other than corn

Since most ruminants are not raised under roof and are exposed to the sun much of the time, ample vitamin D is usually synthesized in the animal An exception may be dairy cows which are sometimes kept in confinement and have high vitamin D needs for milk production and calcium utilization

7.2 Feeds

Nutritive characteristics of commonly used ruminant feeds are given in Table 7 3 Not all feeds can be listed there, but enough are given so that kinds of feeds can be discussed and compared, especially in relation to the requirements of the animals Table 7-2 should be used for this purpose, since requirements are given there in proportion to the air dry ration (90 per cent dry matter)

Note that dry roughages and concentrates normally contain about 90 per cent dry matter For comparison purposes the author has calculated the nutrient composition of silages and pasture forage on that basis also, in addition to providing ' fresh" analysis values

Since roughages usually are the backbone of ruminant rations, one should compare composition of the available roughage with the animals' requirements in order to determine the nutrients that must be supplied by a concentrate mix Though roughages primarily supply energy, they also provide varying amounts of other nutrients

Roughages are often classed as high, medium, or low quality, depending on their nutritive value Roughages in the *high quality* group contain over ten per cent protein, 50 per cent TDN, one per cent calcium, and a high level of vitamin A Alfalfa hay or silage, lush, growing pastures, dehydrated alfalfa meal and red clover hay meet these requirements (Table 7-3), some other roughages closely approach these levels Such roughages could serve as a complete ration for wintering a 1000-pound pregnant beef cow or maintaining a 120-pound dry ewe (Table 7-2) In fact, considerable protein, calcium, and vitamin A would be wasted with such a feeding program It may be more economical to dilute such high quality roughage with a cheaper feed, adequate in energy but lower in other nutrients The wisdom of such a shift depends on feed prices

Where energy needs are high and maximum roughage consumption is desired, as in high producing dairy cows, roughages of the high quality group are generally used They are more palatable and not so bulky so the animals will *eat more*, digest them more efficiently, and get *more energy value from each pound* that is consumed

Figure 7-2. Roughage is the main energy source for these ewes in New Jersey, and for most ruminants. If high quality, it supplies considerable protein, Vitamin A, and minerals. (American Hampshire Sheep Assn.)

Medium quality roughages are considered to have over five per cent protein, 45 per cent TDN and 0.3 per cent calcium, as well as considerable Vitamin A. Most mixed hays, pasture grasses, early cut grass hay, oat silage, and other similar roughages fit this group. By comparing the percentage composition of these roughages (Table 7-3) with the nutrient requirements of ruminants expressed as a percentage of the air dry ration (Table 7-2), it is easy to see what deficiencies of the roughage need to be supplied in a concentrate mixture.

Low quality roughages—corn cobs, straw, hulls, and similar coarse feeds—are used primarily during stages in the life cycle where energy requirements are low and where these roughages can be supplemented with roughages from the high quality group and/or concentrate mixtures. These low quality roughages usually contain none to four per cent protein, about 40 per cent or less TDN, negligible quantities of minerals, and little or no vitamin A.

TDN really does not give a fair appraisal, but rather *overestimates* the productive energy value, of low quality roughages. Since these feeds are very bulky and coarse, considerably *more energy is expended* by the animal in chewing and digesting the roughage and excreting the undigested material, so less net energy remains for growth and other functions. Such low quality roughages are used more efficiently by mature cattle, such as two-year-old steers being wintered at a low level so they can make maximum use of the following summer grasses, or pregnant cows. Sheep or younger cattle would use such feed less efficiently.

The previous discussion indicates that concentrate mixtures or supplements for cattle should be formulated according to the amount and quality of roughage used, in relation to the animals' total nutrient requirements.

Obviously, then, concentrate mixtures to be fed with low quality roughages must be more complete and higher in certain nutrients They must be high in protein, minerals (not just calcium, but others as well), and vitamin A, and provide needed energy Such concentrate mixtures will be expensive and will be composed of a longer and more complex list of ingredients But they will be practical and will allow the animal to utilize a low quality roughage that might otherwise be wasted

Though grains do supply protein, certain minerals, and vitamins, they are fed primarily to supply *energy* for cattle and lambs in the feed lot, cows or ewes during lactation, or to maintain breeding herds in emergency periods when roughages are scarce or too expensive Barley is a commonly grown feed grain for cattle and sheep in the Northwest, grain sorghum is most plentiful in the southern plains states and the Southwest, and corn is the primary grain for ruminant rations in most of the remainder of the United States Wheat, because of price, is used for livestock feeding only when damaged or otherwise unmarketable for human food Some rather bulky concentrates, such as beet pulp, distillers grains, and screenings, are used in ruminant rations when price permits Cattle and sheep can utilize these feeds better than can swine or poultry

A smaller variety of *high protein* concentrates are used in formulating ruminant rations than are used in rations for non ruminants, because balance of amino acids is not so important in rations for mature cattle and sheep Since the microorganisms in the rumen of these animals can synthesize all amino acids used in body metabolism, it is important only that enough total protein be supplied so this synthesis can occur

Therefore, certain expensive high protein feeds that are needed by nonruminants to supply critical amino acids can generally be ignored in ruminant nutrition Here it is usually most practical to use the cheapest source of protein (nitrogen) Certain nonprotein nitrogen compounds are often used in supplements or rations for ruminants, if such compounds can provide nitrogen for the organisms cheaper than it can be provided by oilmeals (Sec 4 5) For efficient and safe use of these nonprotein nitrogen compounds, the amount used should be restricted Urea is usually used to supply only about one third of the total nitrogen in the ration The animals must be on a rather high grain ration and in good health Other precautions are provided by distributors of such feeds, and the distribution and level of use usually is controlled by state regulatory officials

7.3 Feed Consumption

Bulkiness, moisture content, and palatability of feeds must be considered in ration formulation A ration formulated for one day, that contains the quantities of nutrients the animal needs but supplied by bulky ingredients totalling more than the animal can or will eat, does not provide adequate

nutrition. The daily feed figures suggested in Tables 7-1 or 7-2 serve as a guide in formulating rations.

The tremendous volume of the ruminant stomach compartments does allow a greater volume of feed intake and greater use of bulky feeds than is true for non-ruminants. Consumption of air dry feed usually ranges from about 2.4 per cent of body weight in older animals on a maintenance diet to about three per cent in fattening lambs and cattle.

Daily consumption of pasture forage, and the nutrients it contains, can be estimated if the composition of the forage (including moisture) is known. Unless the pasture is extremely high or low in palatability, ruminants usually consume about as much "dry matter" in the form of pasture as they would in equally palatable air dry feed. With such information estimated, nutrient intake from pasture can be compared with the animals' requirement to determine if the pasture provides a "balanced" diet.

Relative dry matter is also used as a guide in predicting silage consumption, except where the silage is extremely wet and soggy and therefore unpalatable. Because most silages contain about 30 per cent dry matter and hay contains about 90 per cent, three pounds of silage is considered about equivalent to one pound of hay. Corn silage and sorghum silage, however, should be considered mixtures of both roughage and concentrate, since they contain grain as well as forage, and supply considerably more energy on a dry matter basis than does grass silage.

7.4 Roughage to Concentrate Ratio in Fattening Rations

Under normal feeding conditions there is an apparent limit to the proportion of concentrates that can be used effectively in ruminant rations. This is naturally not a problem under range conditions or with cow herds and ewe flocks in other areas where little concentrate feed is used, but is of concern to cattle and lamb feeders. The limit is more obvious in *lambs* where "overeating" disease (enterotoxemia) is quite common. It also occurs in cattle. This disorder is apparently caused by a specific strain of organism in the digestive system. This organism, *clostridium perfringes,* which produces a toxin that makes cattle or lambs "go off feed" and that can cause eventual death, apparently develops and flourishes when animals receive a high concentrate ration.

When lambs are started on grain too fast, some will overeat. The first symptom is failure of lambs to come up to the bunk at feeding time. They move about slowly, if at all. Usually they stand in a corner or near the fence, with their back arched and head down. Many feeders maintain a "hospital" lot to handle these lambs. They are taken off all grain immediately, given only hay and water for several days, then started back on grain very slowly.

Because of the universal prevalence of this organism and the sensitivity

it has to concentrates, lamb feeders traditionally start feeder lambs on grain slowly. When 60-pound to 70-pound feeder lambs are purchased from range areas they usually have never eaten grain, having grown on grass and milk. Careful feeders usually offer the lambs only hay after arrival, then feed a small quantity of oats (more bulky than corn) each day. Corn or sorghum then gradually replaces the oats and is increased to about half the ration in three or four weeks Experienced feeders in some areas are able to increase the proportion of concentrate faster and sometimes go as high as 60 or 65 per cent of the ration. Mixing a complete ration, using ground ingredients, or mixing and pelleting the ration often helps prevent enterotoxemia (Figure 7-3). This may be because mixing and pelleting prevent certain lambs from "sorting out" a higher proportion of concentrates, possible when ingredients are fed separately.

Lambs can be vaccinated as an aid to prevent enterotoxemia, though caution in feeding still must be practiced Also, some current research studies are under way to find other techniques for getting lambs "on feed" faster. This is economically important because consumers prefer retail cuts from lambs that are well finished by the time they weigh 100 pounds.

Though most midwestern lamb feeders have tried to use a *high* proportion of concentrates, feeders in the arid Southwest have successfully finished lambs at about 100 pounds using pelleted or cubed rations containing as much as 70 or 80 per cent roughage The success of this type of feeding program, in addition to research findings at certain experiment stations, suggest that the optimum "physical balance" between roughage and concentrate may be different in pelleted rations than when rations are not

Figure 7-3. These lambs in the Southwest are fed a mixed and pelleted ration in self-feeders There are about 10,000 lambs included in this photo (*Western Livestock Journal*)

Figure 7-4. Cattle with good conformation are fed higher proportions of grain, though they still eat considerable roughage (American Angus Assn)

pelleted. There is evidence that pelleting improves the utilization of some feeds. The improvement is apparently larger in rations with a high proportion of roughage, especially if the roughage is low quality.

Research at the Kansas and Nebraska Agricultural Experiment Stations indicates there is a limit to the amount of concentrate fattening cattle will consume *even* when roughage is restricted. Cattle were fed rations composed of corn or grain sorghum and hay with ratios of concentrate to roughage ranging from 1:1 to 5:1. Though there were some differences depending on age, weight, and sex of cattle used, ratios of concentrate to roughage above 3:1 usually did not cause faster gains or produce higher quality carcasses.

Though cattle are not as susceptible to overeating disease as lambs, the problem is not uncommon and cattle are usually started on grain slowly. The proportion of grain is then increased and roughage decreased until the desired proportion is reached.

This desired proportion of grain depends on the weight and quality of cattle being fed Relatively more grain is fed high quality cattle with good conformation, since they can potentially produce high grade carcasses that will sell for a relatively high price (Figure 7-4). Low quality cattle, angular and otherwise poor in conformation, could not yield choice or prime carcasses regardless of the proportion of concentrates fed, so are usually fed a more economical, high roughage ration.

7.5 Formulating Rations for Beef Cattle and Sheep

Designing a ration for a ruminant for one day, using requirements such as those in Table 7-1 as guides, usually involves only trial and error. Live-

Feeds	Daily feed lbs	Total protein lbs	Digestible protein, lbs	Digestible energy TDN, lbs	Digestible energy Therms	Cal-cium, gms	Phos-phorus, gms	Vit A I U	Vit D, I U
Corn silage	5 00	0 11	0 08	0 92	1 85	2 27	1 59	11,600	270
Alfalfa hay	1 50	0 22	0 10	0 75	1 53	10 22	1 66	5,920	1 358
Corn, yellow	1 00	0 08	0 06	0 8	1 62	0 09	1 22	520	-
Total	7 5[1]	0 41	0 28	2 47	5 00	12 58	4 47	18,040	1,628
Requirement	4 60	0 30	0 2	2 40	4 60	4 60	3 50	3,240	350

[1] Approximately 5 8 lbs on an air dry basis

Figure 7 5 A one-day wintering ration for a 140 pound pregnant ewe in the last six weeks of gestation This ration is nutritionally adequate palatable and usually economical Extreme surpluses of calcium vitamin A and vitamin D are not harmful

Ingredients	Pounds of feed	Total protein lbs	Digest-ible protein lbs	Digestible energy TDN lbs	Digestible energy Therms	Cal-cium lbs	Phos-phorus, lbs	Vitamin A, I U
Grain sorghum	1110 0	122 0	98 6	908 0	1831 0	0 22	3 00	
Mixed hay	400 0	35 2	19 2	195 0	390 0	3 00	0 76	2 560
Corn cobs	200 0	4 0		91 0	184 0	0 22	0 08	
Cottonseed meal	50 0	20 6	17 2	33 0	07 0	0 07	0 02	
Urea	10 0	20 2	21 0					
Molasses, cane	200 0	6 0	5 4	110 0	222 0	1 00	0 10	
Dicalcium phosphate	5 0					1 30	1 00	
Salt	5 0							
Pre-mixes	20 0							500,000
Total (lbs)	2000 0	214 8	101 6	1333 0	2700 0	6 41	5 82	502,560 I U
Calculated analysis		10 7%	8 0%	08 0%	1 35/ lb	0 32%	0 28%	251/lb.
Requirement		10 0%	7 5%	05 0%	1 30/ lb	0 20%	0 20%	240/lb

Figure 7 6 A ton of complete ration for 800 pound yearling cattle Proportions of concentrate to roughage would vary, depending on quality of cattle and how long they have been on feed Quantities of nutrients supplied by each ingredient illustrate differences in feed values Premixes may supply other vitamins trace minerals and/or additives Since the premix carrier may be grain or oilmeal it may also supply small quantities of other nutrients See Section 4 5 on protein equivalent supplied by urea

stock feeding experience provides clues to typical rations that will "do the job" and new rations involving different ingredients are most often simply modifications of rations formerly used.

It is obvious that a ration must be palatable, economical, and easy to handle. Consideration of these factors may be sometimes more important than meeting the exact nutrient level listed. And, as was previously pointed out, nutrient requirements must be interpreted according to condition of the animals, feed prices, and other factors. A one-day ration for a pregnant ewe is given in Figure 7-5.

Expansion of feed yards and development of power equipment for feeding have allowed and promoted the use of complete rations for lambs and cattle. Also, some research suggests quicker adaptation to fattening rations and more efficient utilization of feed when the ration is completely mixed, or mixed and pelleted. Complete rations can be formulated with extreme precision, using requirements given in Table 7-2.

Ratio of concentrate to roughage must be considered when complete rations are formulated, and provision must be made for supplemental minerals, vitamins, and feed additives. The relative amounts of grains and oil-meal used in the concentrate portion of the ration are usually dependent on protein content. Algebraic procedures, similar to those used for formulating non-ruminant rations (Figure 6-4), can be adapted to formulate ruminant rations and mixtures. A typical complete steer fattening ration is listed in Figure 7-6.

7.6 Dairy Calves and Growing Heifers

Whereas beef cattle and sheep are raised primarily for production of top quality meat, dairy heifers are raised for maximum milk producing capacity. The same nutrients are needed and, in general, the same feeds are used. There are several items, however, that might be considered unique in feeding dairy cattle.

Calves in most dairy herds are not allowed to nurse their mothers after the colostrum period because the cow's milk becomes ready for sale. Grade A milk is valuable enough that calves are given only a limited amount of milk, or are shifted quickly to a dry or liquid milk replacer (Figure 7-7). A milk replacer must contain all needed nutrients, including the essential amino acids and B vitamins, and it must be highly digestible and high in energy. Most contain 50 per cent or more of milk by-products, and are mixed with water and fed as a liquid (Figure 7-8). Because calves are functionally non-ruminant animals, the principles expressed in Chapter 6 are applicable to dairy calf nutrition. (Nutrient requirements and recommendations were given in Tables 6-1 and 6-2.)

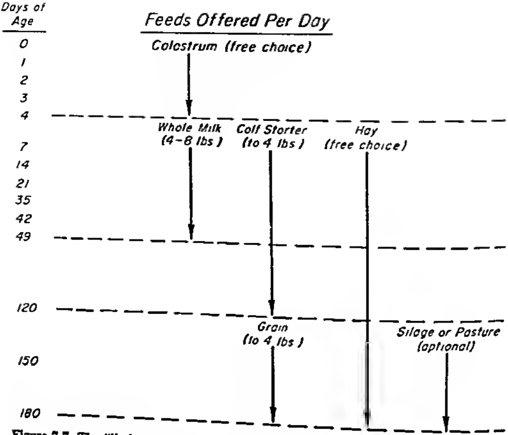
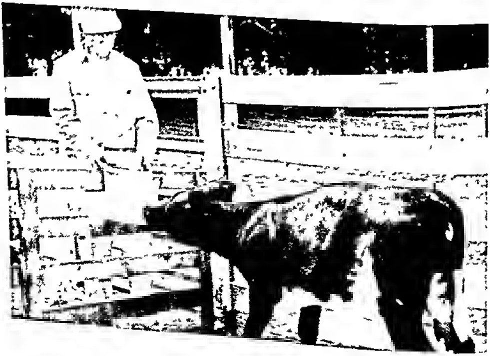


Figure 7-7. The "limited whole milk—dry calf starter—hay" system of raising dairy calves. A milk replacer may also be used. Amounts of each feed depend on size of calf. (Adapted from *Iowa State University Ext. Pamphlet 258*)

Figure 7-8. A calf will usually learn to drink milk or milk replacer more quickly from a nipple pail. (Iowa State University)



Whether calves nurse or are fed on whole milk or milk replacer, they should be offered both concentrate and roughage from four days of age. Especially if calves are on a milk replacer, the concentrate should be a good "calf starter," low in fiber, highly palatable, and containing 18 to 20 per cent protein. Because of the limited capacity of the calf's digestive tract, hay is usually more practical than silage or extremely lush pasture.

The change from a functional non-ruminant to a functional ruminant begins relatively early in the calf's life, and is continuous (Sec. 5.5). Because mature dairy cows receive such a high proportion of their nutrients from roughage, and because a growing heifer is maintained a long time before she becomes productive, it is important that the calf be fed to encourage early, maximum development of the rumen. As the rumen grows and becomes a larger proportion of the stomach, a calf is better able to utilize hay, silage, and pasture.

As a calf matures he also can utilize cheaper concentrates as energy sources. He can manufacture some of the essential amino acids and B vitamins in the rumen. The protein requirement, as a percentage of the ration, declines slightly. The concentrate mix that the calf receives, therefore, can be formulated with less expensive ingredients.

Of concern in raising dairy calves is the fact that most are raised in confinement, where disease is more prevalent and more easily spread, ventilation may be poor, and the calf can manufacture little vitamin D from the sun's rays. This means that management and care must be especially good and rations must be high in quality—nutritive value and palatability.

A second unique consideration in dairy cattle nutrition is that growing heifers are fed to grow, not fatten (Figure 7-9). Naturally, dairy breeding stock is automatically selected for the inability to fatten when selection is directed toward high milk production. To hold down costs, to avoid fattening, and to cause maximum rumen development, heifers are raised primarily on roughage.

Overfeeding energy early in the life of a dairy heifer will lower lifetime production, according to a long time study at Cornell University. Trios of Holstein heifers were alloted at random to three levels of energy at birth —65, 100, and 140 per cent of the levels considered "normal"—and fed at these relative levels until they calved. From then all were fed liberally, according to size and production. A summary of available results is in Table 7-4.

Fat deposition in the udder during growth, and therefore less development of secretory tissue, may be the fundamental cause of lower production among cows raised on higher levels of energy.

More cows which were raised as calves on a high level of energy were lost, primarily because of sterility (see also Sec. 11.2) and mastitis. It may be that fat deposition in the udder prevents complete emptying of the udder at milking time, or permits injuries during machine milking, both of which might contribute to mastitis.

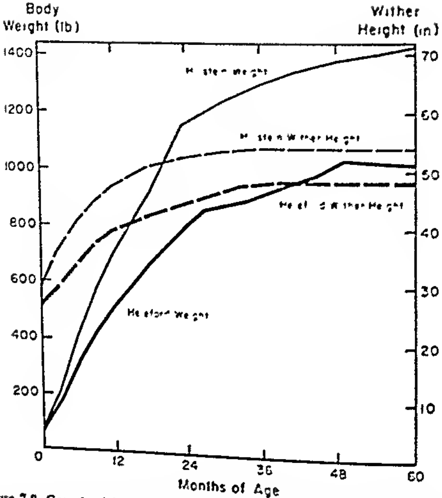


Figure 7 9 Growth of Holstein and Hereford heifers compared both raised under typical systems of management Dairy heifers must be fed for rapid and maximum growth. (Adapted from H P Davis and I L Hathaway *Nebraska Agr Exp Sta Res Bull 179* 1956 and Brown, C J *et al Arkansas Agr Exp Sta Bull 570* 1956)

Table 7-4 Influence of Energy Intake from Birth to First Calving on Subsequent Production*

Feeding level	Low	Medium	High
Number started	33	34	34
Number lost	12	17	17
Sterility	0	3	6
Mastitis	4	10	9
Milk fever	3	0	0
Other reasons[1]	4	4	2
Av days in milk[2]	300	296	284
Av milk production, lbs	11,153	11,008	10,379
Av fat production, lbs	407	419	389

*J T Reid *J Dairy Sci* 43 102 1960 and private communication

[1]Not related to feeding level—rabies hardware disease etc

[2]Averages are per cow and per lactation Some but not all of the cows had completed six lactations

Losses from milk fever among cows raised at a low level of energy intake might be expected. Milk fever is more common among high producing cows since heavy production after calving causes a sharp lowering of calcium blood levels.

Between six and twelve months of age, roughage alone is usually not adequate for maximum growth in heifers. Though the rumen has developed considerably, the energy needs are great enough that two to five pounds of concentrates must also be fed per day for rapid growth. As with other ruminants, the protein level of the concentrate is determined by the protein content and consumption of the roughage.

By the time heifers are one year of age they are usually able to consume and utilize adequate levels of nutrients in the form of hay, silage, and/or pasture. Concentrates—grains or protein supplement—are needed only if the roughage is low quality.

7.7 Dairy Cows

Examples of nutrient requirements for dairy cows are given in Tables 7-1 (per day) and 7-2 (proportion of the ration). These examples are given only to illustrate (1) how requirements are stated, and (2) the magnitude of the difference in requirements for animals differing in production. The main factors which influence requirements are weight, production (volume and butterfat), and stage of pregnancy.

Principles of formulation mentioned previously for other ruminants apply to dairy cattle. Because roughage is usually a more economical energy source, and because energy requirements for good milk producers are so high, good quality roughage that is palatable and well utilized is important. Cows in milking herds are usually provided all the roughage they will eat as hay, silage, pasture, and/or freshly chopped forage (Figure 7-10). Most

Figure 7-10. Good quality forage—grass, hay, or silage—is the backbone of a dairy cow ration. (Holstein-Friesian Assn of America)

cows will eat two to three pounds of hay per 100 pounds of body weight Consumption of 'wet' forages is usually comparable, on a dry matter basis

Good milk cows just can't eat enough forage to provide all the energy they need for maintenance, milk production, and pregnancy Therefore a concentrate mix is usually fed at milking time It is formulated according to the nutrient composition of the roughage the cows are eating, the amount fed each cow is individually governed by estimated roughage consumption and volume of milk production An example of a one-day ration for a large, good producing cow is given in Figure 7-11

Feeds	Daily feed lbs	Total protein, lbs	Digestible protein lbs	Digestible energy: TDN, lbs	Digestible energy: Therms	Calcium gms	Phosphorus, gms	Vit A, I U
Grass silage	25 00	0 90	0 50	3 875	8 75	38 30	13 60	171 000
Corn silage	25 00	0 575	0 30	4 575	9 25	11 00	8 00	58,000
Red clover hay	15 00	1 80	1 08	7 770	15 75	28 00	4 00	125,400
Corn and cob meal	15 00	1 05	0 765	10 980	22 20	2 50	15 00	6,300
Soybean meal	2 00	0 88	0 82	1 544	3 12	3 00	6 00	
Dicalcium phosphate	0 10					11 80	8 20	
Total (lbs)	82 10*	5 205	3 465	28 744	59 07	92 60	54 80	360 700
Nutritive requirement		5 47	3 32	27 40	55 60	71 00	53 00	22,400

*Approximately 44 pounds on an air-dry basis

Figure 7 11 A one day ration for a 1400 pound dairy cow producing 60 pounds of 3 5 per cent milk. The roughage is usually fed separately and the concentrate portion mixed for feeding at milking time

A liberal supply of clean, fresh water is especially important for dairy cows Milk contains about 87 per cent water Also, considerable water is necessary for digestion and metabolism of the tremendous volume of feed most cows consume Cows in full production will usually drink four to five pounds of water for every pound of milk produced, depending, of course, on temperature, humidity, water content of roughage consumed, and other factors That would be about 30 to 40 gallons per day for the cow mentioned in the caption of Figure 7-11

8

SELECTION OF FEEDERS

"Feeders" are animals that are raised or sold for the purpose of going into an intensive feeding program. The term applies to pigs, lambs, and cattle. Most feeder pigs are raised by the farmer who intends to feed them until slaughter, but an increasing number are raised for sale to another party at or soon after weaning. Feeder cattle may be calves, yearlings, or two-year-olds and usually have grown mainly on their mother's milk and grass in the range and pasture areas. Most feeder cattle are primarily of beef breeding. Many, however, carry considerable dairy breeding. Feeder lambs are sold soon after weaning, usually in the fall of the year, to someone who will feed and fatten them for slaughter.

The term "feeder" is also used to describe the farmer or feed lot operator who *feeds* the purchased or raised animals until slaughter. Most feeding is centralized in the Corn Belt, irrigated areas of the West and Southwest, and other sections where a plentiful supply of grain and other high energy feed required for fattening are available. Development of grain sorghum and corn varieties for different areas, and increased use of irrigation, have diversified and increased the number of feeding areas.

This chapter is devoted primarily to the characteristics to look for in selecting feeders. The *range* that exists among feeders, in ability to gain, utilize feed, and produce high quality carcasses, will be emphasized and illustrated. Though Sections 8.1 and 8.2 do preview where and when most feeders are bought and sold, these topics will be treated more thoroughly in Chapters 20 and 22. Chapter 21 provides a full discussion of all market classes and grades.

8.1 Where to Buy

Many feeder cattle, lambs, and pigs are purchased through terminal markets, auctions, or dealers of various types. The remainder, an increasing percentage, are sold by a direct arrangement between grower and feeder. Feed lot operators who feed large numbers and who are relatively capable of evaluating animals can well afford to make direct purchases, thereby saving some marketing costs. Most purchasers, however, prefer to

have a dealer—someone who is more familiar with livestock values and current prices—represent them in buying feeders.

Regardless of the manner of marketing, directly or through a dealer or established market, it is important to know and consider the *reputation* of the producer or rancher who grew the animals. This is particularly true in cattle and sheep where breeding herds and flocks are relatively stable and do not change rapidly in genetic make up. Characteristics that are influenced by heredity, such as rate of gain and potential carcass merit, tend to be consistent year after year in feeder cattle or lambs from the same herd or flock. Rate of gain and carcass quality are also inherited in swine, so performance of previous groups of hogs is a good indicator of the potential value of a current pig crop from a certain herd.

Producers also develop a reputation concerning management, disease control, and honesty in business dealings. Management and disease control during the early life of a pig greatly influence his later performance, so it is good business to patronize only those producers and dealers who sell or handle healthy, vigorous pigs. The same is true for other species.

8.2 When to Buy

Most feeder lambs and feeder cattle are purchased in the late summer and fall months (see Figure 22.2, page 308). Ranchers in the range and pasture areas, who produce most of the feeders, prefer to market at the end of the grazing season for several reasons. Gains during the summer months on lush grass are rapid and economical; cattle are usually in good condition in the fall. Calves, normally born in early spring, have just been weaned. Winter feeding would be expensive, gains would be relatively slow and cattle may not maintain good fleshing through the winter. Also, harvested feed costs more than grass, and is less palatable and lower in energy.

Most lambs in the range areas are born in the spring and must be sold as feeders before fall. Not only is the cost of wintering high, but more importantly, lambs must be relatively young and light when they enter the feed lot. Fat lambs are valuable only if slaughtered before they are a year of age and before they weigh much over 100 pounds. Feeder lambs at weaning time weigh about 65 to 70 pounds and usually need two to three months on a more concentrated ration to reach the "choice" grade. (In some cases, where grass is especially high in energy, lambs do have enough finish for slaughter soon after weaning, so are never sold for "feeding." Such is the case in most farm flocks in midwestern and eastern states, though a grain mix is often creep-fed.)

Not only do ranchers prefer to sell their "feeders" in the fall, but many farmers and feed lot operators have traditionally desired to buy then. The farmer who grows grain to market through livestock has more labor available by the end of summer. By then, he can safely estimate the amount of

feed he will have available and so can better determine the number of animals he should buy.

The desire of ranchers to sell in the fall slightly overshadows the desire of feeders to buy. Heavy supplies of feeder lambs and calves during September, October, and November usually cause slightly lower prices, indicating demand does not increase as much as supply. This topic is discussed in detail in Chapter 22.

Obviously feeder cattle and lambs are produced in other than range areas and are sold every week of the year in varying numbers, but it is interesting to note the strong seasonality of feeder cattle and lamb movement. Since ranching areas produce mainly grass which is most effectively harvested by ewe flocks and cow herds, since seasonal climate makes lambing and calving in the spring more practical, and because economical pasture is gone before winter arrives, this heavy marketing in the fall of weaned lambs and calves, as well as yearlings and two-year-old cattle, will probably continue.

Any seasonal peaks in movement of feeder pigs are not large because farrowing is not as greatly influenced by season as lambing or calving. There is *some* seasonal effect; a peak in farrowing occurs in early spring and a smaller peak occurs in late summer or early fall. Most feeder pigs are sold, however, by experienced hog men who specialize in raising them. They farrow groups of sows often during the year, usually in buildings that counter climatic effects, so pigs are available the entire year.

A flurry in feeder pig movement often accompanies sharp changes in prices of slaughter hogs. Specialized feeder pig producers usually do not contribute to these flurries, but rather farmers who hope to predict what prices will be when such pigs are ready for slaughter, in relation to current price. Those optimistic will buy; those pessimistic want to sell, even though they may have ample feed available and the pigs may be considerably past weaning.

8.3 What to Buy

Type of feed available is the main factor in determining what kind of feeder to buy—species, age, weight, sex, and quality. Hogs eat concentrates—grain, plus supplemental protein, mineral, etc. They will not serve as a market for roughage. Heavy, mature, and relatively low quality cattle (sometimes of dairy breeding), however, may provide an ideal market for hay, silage, grain stubble, and mature pasturage that would otherwise rot down during the winter. Depending on weight, age, and quality, grain or grain silage is usually added to the ration for a short time before slaughter to increase the fatness and juiciness of the meat. Higher quality cattle will utilize higher proportions of grain, in addition to forage. The same is true for lambs.

Lambs provide an excellent market for wheat pasture, a cheap and plentiful feed in the winter wheat area if ample fall rains have given good growth Lambs will graze close, causing the wheat to stool out but not damaging it They are light so do not tramp out the wheat in rainy weather Lambs on good wheat pasture will reach the choice grade before the end of the wheat grazing season

Capital—amount, interest rate, and length of credit—is also an influencing factor Hogs, for example, must be fed higher proportions of high protein supplements not grown on farms, while cattle and lambs can often get ample protein from farm-raised legume hay or silage Or, if farm-raised feeds are low in protein, proportionally *less* protein supplement needs to be purchased because of the lower protein requirement of ruminants (Table 7-2 vs 6 2), and the protein supplement will be simpler and less expensive

More total capital is usually needed to *buy* enough cattle or lambs to market a certain quantity of grain if hogs were used for the feeding enterprise This means that relatively more risk is involved in feeding cattle or lambs, at least from the standpoint of money invested and potential price fluctuations affecting the total value of animals purchased

One who wants to feed livestock should also be influenced by personal likes and abilities, and labor and facilities available Obviously, current prices of the various kinds and types of feeders available, compared to the anticipated value of the finished animals ready for processing, is a major consideration

8 4 Range in Performing Ability

There are tremendous ranges in performance characteristics of meat animals—rate and efficiency of gain, carcass grade, and the percentage of lean

Four calves sired by one Hereford bull, on test at Panhandle A and M College, Goodwell, Oklahoma, gained an average of 3 18 pounds per day on only 753 pounds of feed per 100 pounds of gain Another group sired by a different bull gained well, 2 63 pounds per day, but required 1,180 pounds of feed per 100 pounds of gain Assume you purchased the calves at 450 pounds and fed them until slaughter at 900 pounds If they sold for the same price (which is doubtful) and the ration cost two cents per pound, you could have paid $8 54 *more* per cwt for the good calves as feeders This difference *does not include* such factors as saving in labor, interest on investment, and risk Also cattle which gain slower often do not grade as high, even at the same market weight

Offspring of different boars, on feed from 60 pounds to 200 pounds at the Iowa Swine Testing Station, have differed as much as 80 pounds of feed per 100 pounds of gain In the fall of 1956, one group of hogs gained on 256 pounds of feed per 100 pounds of gain, while the poorest group

required 312 pounds of feed for the same weight increase. With the ration costing three cents per pound, each one of the more efficient feeder pigs would have returned $2.35 more profit per head. Or, in appraising the pigs as 60-pound feeders, the better pigs were worth about $4.00 more per cwt.

Similar ranges exist in feed lot performance of lambs.

8.5 Inheritance

Important performance traits, which vary so greatly among animals and among herds or flocks, are highly inherited. Since this means the traits are largely passed to the offspring from the parents, careful selection of breeding stock within and for herds and flocks for feeder production is worthwhile.

It pays a rancher to practice careful selection of bulls and replacement heifers, considering these important production traits in addition to prolificness of parents. Some progressive ranchers use only performance-tested bulls, whose rate and efficiency of gain in a standard feeding trial have been outstanding and which may have sired calves that produced top quality carcasses. Certain of these ranchers have followed their calves to commercial feed lots to check gains and efficiency, and finally to packing plants where they measured the rib eye muscle and other carcass traits. They use this information to evaluate herd bulls or for selecting replacements closely related to certain good performing animals.

Selection of swine breeding stock for rate and efficiency of gain, as well as for carcass merit, has gained great momentum in midwestern states.

Though selection of rams and ewes on these bases is as important to the sheep industry as the previously mentioned programs are to the swine and cattle industries, less attention has been devoted to it. The sheep industry is a smaller industry, and therefore has not received the attention of various educational and advisory groups in setting up testing and appraisal programs for breeding stock. Because each lamb is on feed a shorter period and consumes much less total feed than a steer, benefit to be gained by rigid selection of a sire for feed efficiency is less. True, if enough lambs are fed, the total benefit to the feed lot operator could be as great, but more cost would be involved in any testing program because of the larger numbers of individual animals involved.

A rapidly increasing number of producers are improving their herds and flocks by techniques mentioned above and by other methods, so are fast establishing a top reputation as a source of good feeders. They, therefore, can demand and receive top prices.

It is not possible, however, to always know the performance background in selecting feeders. Later sections, therefore, discuss other factors important in selection and the value of certain traits as *indicators* of performance and profitability.

A Feeder Cattle

Feeder cattle are produced in all sections of the country, but most are raised in grazing areas, where mature cows can do the best job of marketing available forage Figure 8-1 indicates some of the major feeder cattle and lamb producing areas The southeastern states have become more important suppliers of feeder cattle in recent years, with the return of much of the former cotton land to grass and the development of breeds and strains of cattle more resistant to heat and insects (see Figure 1-2) The Rocky Mountain states and the arid Southwest, including Texas and Oklahoma, have long been important feeder producing areas Other localized pasture areas, in Tennessee, Kentucky, southern Illinois and Iowa, northern Missouri and other states, also account for a considerable number of feeder cattle, usually produced in smaller herds

With increased competition from feed lots in the West and Southwest for feeder cattle produced in the mountain states, some interest has developed in raising feeder calves in the Corn Belt Cow herds can be maintained on roughage that is a by product of grain production or on rotation pastures The former may involve feeding the roughage to the cows in *confinement* most or part of the year, which would present numerous management and labor problems

8 6 Breed

Quality in feeder cattle is not necessarily related to breed Good and poor animals are found in all breeds The range within breeds is *much* larger than the range in characteristics among averages of breeds

The predominant breeding in range herds is Hereford, so a majority of cattle sold for feeding are "white faces" There seems to be some increase, however, in the use of Shorthorn and Angus in range herds Until recent years, many animals in the Angus breed have been considered too small to cope with the rugged conditions prevailing in range areas Current selection however, seems to be directed to larger, more rugged animals

Though the benefits of crossbreeding (see Chapter 18) in commercial cow herds have been demonstrated repeatedly, there has been considerable hesitancy to practice crossbreeding Corn Belt and other cattle feeders have discriminated against crossbred feeder cattle, apparently preferring and taking pride in uniformly colored, well marked cattle, and fearing that some crossbreds may have other than "beef" breeding in their ancestry Fearing this discrimination perhaps wisely in the *short run*, few ranchers have adopted crossbreeding as a practice, though it could be beneficial to them as well as to the feeder It is apparent that a rancher who consistently produces good quality crossbred calves will develop a valuable reputation and,

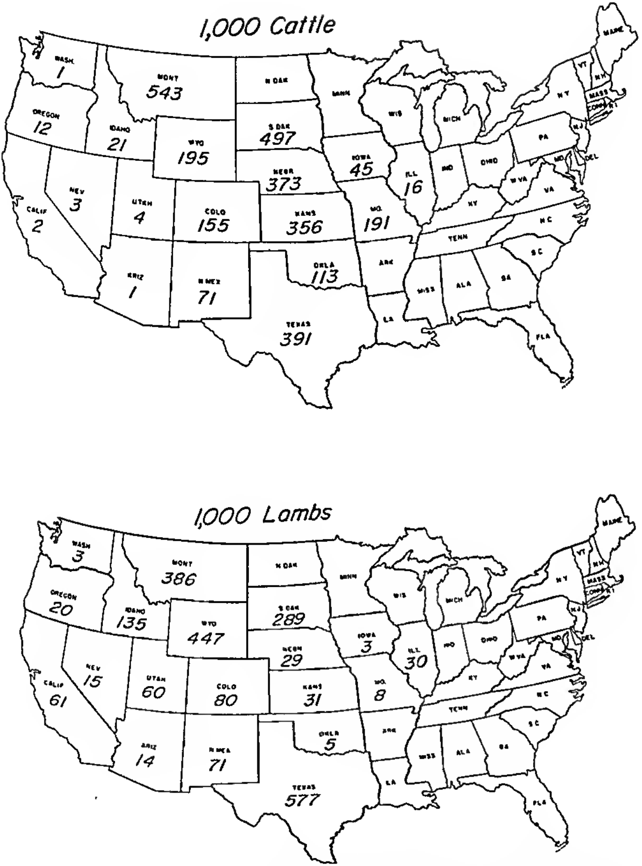


Figure 8-1. Sources of stock and feeder cattle and feeder lambs shipped direct into North Central states, 1960. States marked supplied about 80 per cent of the cattle that went into this major feeding area and 94 per cent of the lambs. Note some shipments within and among the North Central States. (AMS, USDA)

in the *long run*, may profit both because of better performance before weaning and because of the demand for a vigorous calf that will perform well in the feed lot

Rather than use two or more breeds to produce crossbred calves with diverse color markings, many ranchers have tried to reap some of the benefit of crossbreeding, and still maintain uniform color in offspring, by using bulls from a different "line" or "family" than the cow herd, but within the breed Such bulls would be relatively unrelated and some hybrid vigor would result Much research by state experiment stations and the USDA has been directed toward development of lines within breeds for this purpose, and, perhaps, for crossing between breeds

Some other breeds, including Brahman, Charolaise, Santa Gertrudis, and Charbray, as well as animals that are crosses between these and the English breeds (Hereford, Angus and Shorthorn), have been used heavily in the southern and southeastern states because of their resistance to extreme heat and to certain insects prevalent in these areas

Cattle of the larger dairy breeds should not be ignored in this discussion Many feeders market considerable roughage, and some grain, through Holstein, Ayrshire or Brown Swiss steers, or crosses involving these breeds Such cattle normally gain faster, produce more carcass per pound of feed, and have a higher percentage of lean in the carcasses Carcasses grade lower because there is less marbling in the muscle and because they are less symmetrical When comparisons have been made, however, there has been little difference in percentage of primal cuts (Table 8-1)

Cattle of this larger type do not accelerate in fattening until heavier weights are reached, so gains to any given weight are more efficient A larger percentage of lean and a smaller percentage of fat is deposited with each pound of gain

In countries where meat producing capacity is taxed because of intense population, a larger percentage of beef consumed is from animals of dairy

Table 8 1 Growth and Carcass Data on Beef and Dairy Breed Steers*

Item	Herefords	Holsteins
Number of animals	7	7
Initial weight, lbs	765 00	781 40
Final weight, lbs	1,017 90	1,089 60
Av daily gain, lbs	1 88	2 34
Feed per pound of gain, lbs [1]	13 40	11 32
Dressing per cent	59 00	59 50
Primal cuts, per cent of carcass[2]	58 80	58 90
Per cent muscle in rib cut	54 00	59 50
Per cent protein in edible portion of rib cut	14 40	16 90

*James F Kidwell and John A McCormick *J Animal Sci* 15 109 1956

[1]Rations were not the same steers were fed according to quality

[2]Primal cuts of beef are the round loin and rib

breeding. There are several reasons: (1) milk is a cherished food and is produced more efficiently than meat, (2) dairy herds serve a dual function; cull cows and steers provide meat, and (3) cattle of dairy breeding usually produce more pounds of lean per pound of feed.

In the United States, to date, we have been willing to pay a premium for cattle of beef breeding, because of certain quality factors in the lean such as marbling.

Since dairy calves are born all months of the year, it is difficult for a cattle feeder to accumulate a large group of dairy steers of similar age and breeding. Many cattle feeders want only uniform groups for feeding, so dairy steers may be discriminated against at the market and are often a "good buy."

8.7 Age and Weight

The age and weight of feeders purchased, in addition to the species, should depend on the kind and amount of feed, labor, capital, and other such items, available. Feeder calves purchased for feeding soon after weaning usually average only 500 pounds or less (Figure 8-2). Yearling steers or heifers usually weigh between 650 and 750 pounds, and the few two-year-old cattle usually weigh 800 pounds or more. Older and heavier cattle, if good quality, are put on a concentrate ration rapidly in order to produce "choice" carcasses before the animals pass the ideal market weights.

The "ideal" market weight is impossible to define since it depends on

Figure 8-2. "Fancy" feeder calves, on a Nebraska ranch, sorted for shipment (American Hereford Assn)

quality and finish of cattle and also consumer demand, both of which vary greatly. In recent years, however, it has been practical to feed good quality yearling steers and heifers to the choice or prime grades at about 1050 to 1100 pounds, while the small number of two-year-old cattle have been commonly marketed at 1200 to 1300 pounds, grading choice or prime.

Naturally, because lower quality cattle would usually not be fed to such heavy weights, much less concentrate but more roughage would be used.

Purchased calves are usually allowed to "grow" on hay, silage, grain stubble, and other forage before being confined in a feed lot for fattening. The reasons are to provide a market for this roughage which might otherwise be wasted and to let the calves grow on a cheaper feed than concentrate. A later feeding period on a high grain ration, ranging from 120 to 200 days depending on quality of cattle and feed, will put good quality calves in the choice grade at 900 to 1000 pounds.

It may be less profitable to finish livestock for market at *too* light a weight. When a finished calf is sold for slaughter the sale price must pay not only for the feed and labor that went into the calf, but also all expenses of (1) growing and maintaining the cow, and (2) the calf's share of the bull cost (both included in the cost of the feeder calf). When a 700 pound finished calf is sold for slaughter the price per pound must obviously be higher, to pay these costs, than if the animal is sold at 1000 pounds.

Countering this effect, however, is the fact that a growing calf (or other animal) becomes *less efficient* as it grows and fattens. So each additional pound of weight is added at a greater feed cost than the previous. The most profitable market weight, ignoring current price fluctuations, is where these two opposing forces balance.

Lighter and younger animals need more shelter and are more susceptible to disease and other stresses, so demand more attention. Less financial risk is involved with calves however, because a smaller animal is purchased and the calves will be fed longer, therefore fewer total animals (meaning less investment in animals) are needed to market a given quantity of feed.

Recent surveys indicate that about 40 per cent of the feeder cattle entering feedlots are calves, about 50 per cent are yearlings, and under ten per cent are two years old or older. The last figure includes a few "stocker" cows.

8.8 Weight Within Age Groups

Among feeder cattle there is a positive correlation[1] between initial weight

[1] Correlation could be defined as the degree of relationship between the rate of change in two variables. A calculated correlation of 1.00 means the correlation is perfect—a change in one variable is associated with a change in the *same direction* and of the *same relative magnitude* in the second variable. A correlation of 0 means that there is no association between changes occurring in the two variables. It is possible to have negative correlations wherein an increase in one variable is associated with a decrease in a second. Correlations are calculated by statistical techniques and can range from −1.00 to 0 to 1.00.

and rate of gain during the feeding period. This means that the heavier animals within a group of feeder cattle will gain faster, on the average, than will the light cattle. This is illustrated in Table 8-2. Note that the correlation was not perfect in this case. Each increment increase in weight from the lightest to heaviest calf was not accompanied by a perfectly corresponding increase in rate of gain. But the trend and association of the two factors, initial weight and rate of gain, are obvious.

Several factors may contribute to the positive correlation between initial weight and rate of gain within a group of cattle. (1) Larger animals can

Table 8-2. Initial Weight and Grade as Indicators of Performance in a Typical Group of Yearling Steers

Steer no.	Initial weight	Average daily gain	Feeder* grade	Slaughter* grade
1	824	2.69	5	9
2	800	2.72	2	7
3	783	1.98	2	6
4	779	2.58	8	9
5	775	2.11	9	5
6	770	3.09	2	6
7	764	2.69	6	8
8	761	2.83	5	9
9	755	2.23	2	6
10	742	2.30	2	6
11	730	1.93	8	8
12	719	2.78	5	8
13	710	2.31	5	8
14	705	2.25	7	8
15	703	2.29	8	8
16	702	1.66	2	6
17	679	2.03	8	8
18	667	2.62	5	8

*Grading Scores Below:
Low medium = 1
Av. medium = 2
High medium = 3
Low good = 4
Av. good = 5
High good = 6
Low choice = 7
Av. choice = 8
High choice = 9

Correlation Coefficients:
Initial wt. x average daily gain = .36
Feeder grade x average daily gain = .14
Feeder grade x slaughter grade = .47
Average daily gain x slaughter grade = .37
Initial wt. x feeder grade = .24
Initial wt. x slaughter grade = .10

eat more feed. Though all are "calves," not all were born the *same day,* so the older animals are more mature, may have a more functional rumen, and can eat more and gain more. (2) If we assume *no* difference in birth date, the faster growth of the heavier feeders in a purchased group must be largely caused by heredity (if all animals in the group were from the same ranch and handled the same). We know that rate of gain is materially influenced by heredity and we would expect feeders who gained relatively fast *before* entering the feed lot to *continue* to gain fast, in relation to other animals in the group. (3) Heavier cattle are more resistant to diseases such as shipping fever, inclement weather, and other stress conditions. (4) Limited bunk space may give heavier cattle some advantage in the feed lot.

These reasons may also explain why the correlation between initial weight and rate of gain is usually higher (closer to 1.00) among calves than among yearlings or older cattle.

Important as part of this discussion is that *efficiency* of gain (pounds of gain per pound of feed) is usually better in *faster* gaining animals. The obvious reason is that a faster gaining animal will be on feed fewer days to reach the desired market weight. Since a large part of the ration consumed is used for maintaining the animal and only the remainder contributes to increased growth, maintaining an animal fewer days means a larger *proportion* is used for gain.

A factor conflicting with the positive association between rate and efficiency of gain is that when cattle *gaining the same rate* are compared, older and heavier cattle are usually less efficient. Their maintenance requirement has increased and also gains made by heavier animals usually include more fat, which requires more energy for deposition than does lean.

Therefore, it must be clear that the positive association between rate and efficiency of gain is *greater* and more noticeable within a group of cattle *very* similar in initial weight. It is apparent, too, that a purchaser of feeder cattle must exercise some judgment in selecting on the basis of weight. If he is selecting from a group of thin calves he knows are uniform in age and quality, he obviously would select the heavier calves. They will probably gain relatively faster in the feed lot and, being calves and being thin, even the heavy calves will be relatively efficient. If they would gain *enough* faster, they could be *more* efficient than the light calves.

On the other hand, if he were appraising 650 pound to 800-pound yearlings carrying considerable fleshing after a good summer on top quality grass, *not knowing* anything about relative age of the cattle, he might select the lighter and thinner yearlings. They probably would be more efficient because they are lighter, not as far along in the *fattening* process, and, since yearlings are closer to the point where the normal growth curve levels off (see Figure 7.9, page 110), the difference in predicted rate of gain would not be large.

8.9 Sex

Most cattle in feed lots are steers or heifers, though a few bulls and cows are fed A majority are steers, since a certain percentage of heifers are retained as cow herd replacements It is often possible to predict increases and decreases in future calf production by the percentage of heifers entering feed lots

Steers gain faster than heifers on similar rations, but heifers fatten quicker, so are ready for slaughter at a lighter weight Some prefer heifers because of the shorter feeding period If feeding raises the grade and value of an animal, the feed lot operator receives a positive "margin," selling the pounds he bought for a higher price than he paid Because of the shorter feeding period (and less feed consumed per animal) he could feed more heifers than steers with a given amount of feed Therefore, he might realize a margin on more animals

The shorter feeding period for heifers may sometimes be considered a disadvantage, depending on feed supplies and anticipated prices of slaughter cattle Heifers often "come in heat" during the feeding period, becoming restless, riding each other, "walking the fence," and gaining little for several days Because of the possibility of slaughter heifers being pregnant, causing a lower dressing percentage, packers often pay less for heifers Though this differential is usually reflected in purchase price of feeders, the gain put on in the feed lot, nevertheless, sells for less

To avoid price discrimination on heifers because of the fear of pregnancy, some ranchers have spayed (removed ovaries) their heifers thereby guaranteeing them to be "open" Several experiments[2] have indicated spayed heifers eat less feed, gain more slowly, and are less efficient

There has been a recent increase in the number of bulls fed for slaughter Bulls generally gain faster and more efficiently than steers and produce a carcass that has a higher percentage of lean Table 8-3 shows the results of bull feeding research at the Ohio Experiment Station There is some prejudice against bulls for slaughter, since most bulls *formerly* sold for slaughter were mature, strong in flavor, and lacking considerably in tenderness Most meat from such bulls is normally used in sausages and other ground and prepared meats

Older cows, such as cull beef or dairy cows, are sometimes confined to a feed lot for a very short feeding period before slaughter, to increase the fatness of the carcass and the juiciness of the meat This is not routine, but is practical if cows are of desirable conformation and are young when culled, yielding relatively high quality carcasses There have been times

[2] C J Kercher *et al* *Wyoming Agr Exp Sta Mimeo Circ 127* (1960)

Table 8 3 Results of Feeding Trials at the Ohio Experiment Station Comparing Bulls and Steers*

	Steers	Bulls
Trial 1 (168 days)		
Number	10 00	10 00
Initial Weight lbs	555 00	529 00
Average daily gain lbs	2 31	2 76
Feed per lb gain lbs	10 77	8 86
Trial 2 (Carcass data only)		
Number	8 00	20 00
Edible portion percentage of carcass	73 17	77 52
Fat percentage of carcass	11 33	6 32
Carcass grade	Av choice	Av good
Tenderness score [1]	8 01	7 27

[1] Score of 9 = very tender, 8 ~ tender, 7 ~ average

*Earl W Klosterman *et al* *Ohio Agr Exp Sta Animal Sci Mimeo Series 87*, 1954, 14, and L E Kunkle private communication

*AMS and ARS, USDA

when drouth has forced heavy culling of beef cows in range areas Market price of these cows (which normally go directly to slaughter) dropped so low that feeders could afford to purchase them to utilize roughages and some grain

8 10 Feeder Grades

To provide a common basis for trading, even when both buyer and seller cannot see the cattle, and to insure meaningful market reports of supplies and prices, grades have been established for grouping feeder cattle by quality The USDA has assumed the responsibility for describing characteristics of the various grades and providing example pictures Since cattle appraisal is rather subjective and depends somewhat on individual judgment, interpretation of grade specifications varies among people There is considerable uniformity, however, and the grades have provided a very useful tool for market reporting and for describing animals to a buyer or seller by phone, wire, or mail (Figure 8-3)

The criteria for the grades now in use are related mainly to conformation According to USDA descriptions, higher grading feeder cattle should be short, wide, and deep bodied, should have a straight top line and underline, and should be relatively uniform in width and depth These criteria are similar to those considered in grading beef carcasses after slaughter Since the relative conformation of the animal doesn t change materially during feeding, there usually is a *high correlation* between feeder grade at the beginning of the feeding period and the carcass grade after slaughter

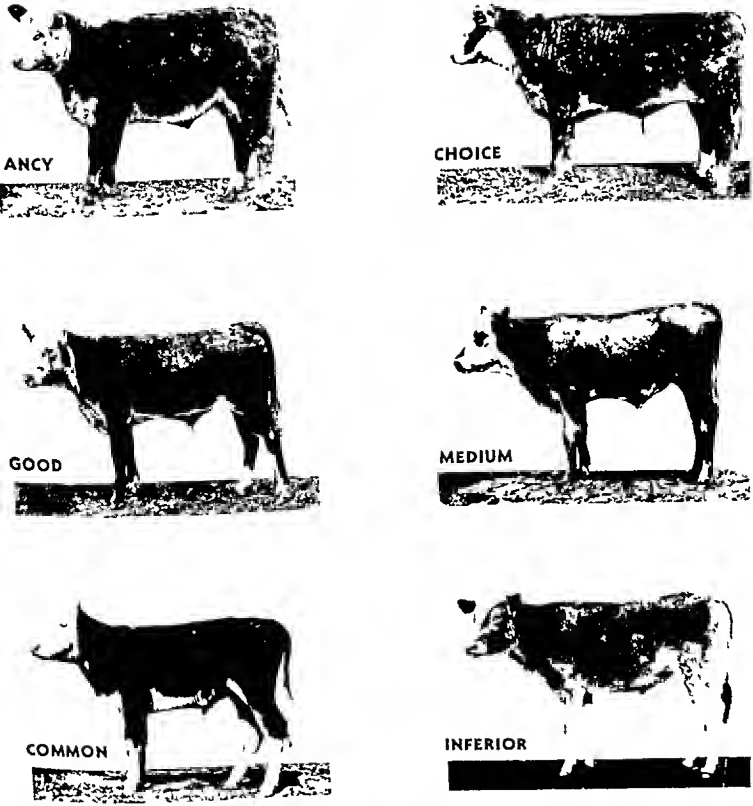


Figure 8-3. USDA picture standards for grades of feeder steers Grade is an indicator of conformation not of rate of gain or feed efficiency (AMS, USDA)

There is *little or no correlation* however, between feeder grade and rate of gain. In fact, some studies have shown a slightly negative correlation between grade and rate of gain—rangier, narrower, and longer legged cattle have gained faster on a similar ration.

Since conformation is important in both carcass and feeder grades, choice and fancy feeders are usually fed a higher quality, more concentrated ration for a longer period to produce the carcass most desired by the consumer. Lower grade feeders do not have the conformation to potentially produce top quality, high value carcass, so are finished on pasture or fed a cheaper, higher roughage ration, and/or are fed a shorter length of time. Such a feeding program would be used, for example, for Holstein feeder steers.

It is clear that feeder grade is a relatively reliable indicator of the grade of the finished carcass, but it is *not* a reliable indicator of rate of gain or feed lot performance. Some high grading feeders will gain fast, some will gain slow. The same is true for feeder cattle in the lower grades. But if feeder cattle are fed according to their quality, high grading feeders will produce high grading carcasses.

8.11 Color

Coat color or density of color is apparently independent of performance characteristics, such as rate and efficiency of gain or carcass merit. Though many stockmen have a personal preference for a certain shade of color within a breed, especially Herefords, research at the New Mexico and South Dakota Agricultural Experiment Stations has shown no performance difference due to color. Good and poor performing animals can be found in all color groups. Probably the reason that some prefer cattle of a certain shade is that they have had either a profitable and pleasant experience growing or feeding cattle of that shade, or an unprofitable experience with cattle of a different shade.

8.12 Other Indicators of Performance

Though records on performance of ancestors serve as a relatively reliable guide to feeder cattle merit because of the *inheritance* of performance traits, research has continued toward finding more direct, simpler, and more accurate indicators of future performance in cattle.

The level of protein bound iodine in the blood is a rather reliable indicator of rate of gain. This measures the activity of the thyroid gland, which secretes thyroxin to control rate of body metabolism. An overactive thyroid, which produces a high circulating level of thyroxin (protein bound iodine), causes rather poor performance because the steer is highly sensitive and restless, using up too much energy in wasted motion. If the thyroid is too inactive, however, circulating thyroxin is low and the animal is too

Table 8-4. Approximate Correlations Between Certain Traits with Feed Lot Performance and Carcass Merit of Cattle

Trait in feeder	Performance	Correlation
Initial weight on	Rate of gain	.30 to .40
Initial weight on	Carcass grade	0
Feeder grade on	Rate of gain	0 to -.10
Feeder grade on	Carcass grade	.40 to .50

sluggish to move about and consume normal quantities of feed. The relationships of other blood components, such as red and white blood cells, proteins, and other chemicals, to feedlot performance have also been studied.

Some measurements which have been studied as possible indicators of feed lot performance and carcass merit are summarized in Table 8-4. Correlations show the relative reliability of the various factors as indicators.

B. Feeder Lambs

Since sheep are well adapted to cool climates, rough terrain, and rather sparse vegetation, a majority of the sheep are raised in the mountain states and arid plains states (see Figure 8-1). Few concentrates are available in the grazing areas, so most lambs are shipped out as feeders soon after weaning unless, in some cases, the lambs carry enough finish to be slaughtered directly off grass.

Lambs raised in midwestern "farm flocks" are usually sold for slaughter at or soon after weaning. Such lambs usually have access to a creep ration in addition to their mothers' milk and pasture, so are finished at an early age, and are not sold as "feeders."

8.13 Age and Weight

Essentially all feeder sheep are sold as lambs, between five and eight months of age. Older animals, after feeding, yield carcasses with an undesirable, stronger flavor. Feeder lambs range from 50 to 90 pounds; most are between 60 and 75 pounds. The consumer desire for light weight cuts and the slow fattening which results from about 50 per cent necessary roughage in the ration, mean that light feeder lambs, weighing 60 to 65 pounds, are desired. Light lambs will be more likely to grade choice by the time they reach 100 pounds (Figure 8-4).

There are other reasons why light lambs may be more profitable for the feeder. Whenever lambs are bought and sold there is marketing expense and considerable transit shrink. If lambs are purchased at 80 pounds and sold at 100 pounds, shrink and marketing costs are high *in relation to* the

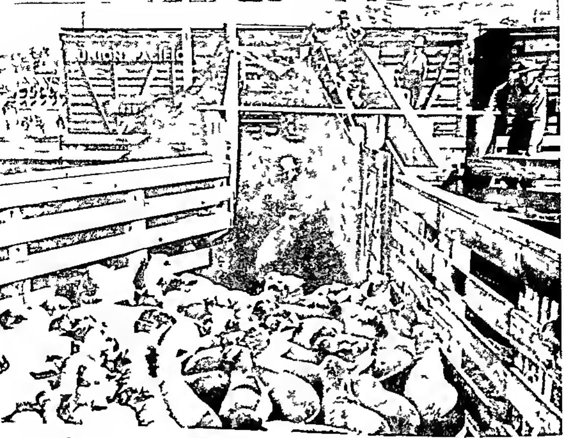


Figure 8-4 Feeder lambs enroute from the West to Corn Belt feedlots (Union Pacific Railroad)

profit that might be made on gain A feeder would need to buy, feed, and sell about twice as many 80-pound feeder lambs to market a certain quantity of feed as he would if he purchased 60-pound feeder lambs Also, the heavier lambs would probably gain less efficiently, on the average, than lighter lambs because a large proportion of the gain is fat, and because their average daily maintenance requirement is higher

As is true with cattle, heavier feeder lambs *of the same age* will gain faster, but because of the other factors mentioned this is less important in lambs

8 14 Breeding and Color Markings

Lamb feeders prefer lambs which show evidence of some mutton breeding—sired by rams of the mutton type breeds (Chapter 19) Sheep of fine wool breeding are narrower, rangier, and produce a less desirable carcass Most ewe flocks in range areas are of fine wool breeding because of the heavy yield of high quality wool and also because their type and conformation make them more adapted to range conditions Many sheep ranchers have found it practical to maintain a fine wool ewe flock, since fine wool is more valuable They breed only enough ewes to fine-wool rams to provide flock replacements, and use mutton type rams on most ewes to produce the meatier crossbred feeder lambs The crossbred lambs are usually more vigorous and gain faster, both on the range and in the feed lot

Hampshire and Suffolk rams—both with black markings—have been popular for such crossbreeding programs, because of their large mature size and ruggedness. Therefore, feeder lamb purchasers have developed the habit of looking for black-faced or dark-faced feeder lambs, knowing they would probably gain faster and produce meatier carcasses than white-faced, straight-bred, fine-wool lambs. In recent years, however, certain white-faced mutton type rams, such as Columbia and Corriedale, have been used, so the black markings have become less reliable as an indicator of cross-breeding, faster gains, and potential carcass merit.

8.15 Grades

Though official grades of feeder lambs have been designated and described, they have less significance in appraising feeder lambs than the grades for feeder cattle. The main reason is that there is less total variation in feeder lamb quality, so less need for grading. Because of (1) the heavy seasonal influence on lamb production, (2) the economic restriction of feeder lamb production to grazing areas, and (3) the limitation on age and weight for lambs entering feeding programs, nearly all feeder lambs are produced under very similar conditions and are sold at equally similar ages and weights. About the only factors which contribute greatly to variation in feeder lamb quality are breeding and health.

In most years, healthy feeder lambs carrying some mutton breeding grade either choice or "good to choice." Lower grading feeders are usually of straight fine-wool breeding, are late lambs that didn't get the benefit of early, lush grass (and their dams probably produced less milk for the same reason), or are from a drouth area short on grass.

Since feeder lamb production is so seasonal and so dependent on grass production, there is much yearly variation in lamb weights and quality. In some years lambs are thin, light, and look poor, though they may be highly profitable to a feeder for these very reasons. Other years rainfall and temperature are such that all lambs are heavy at the end of the grazing season; many carry enough finish to grade high good or choice so are sold directly to packers. Though the lambs are in excellent condition, such years are usually bad for lamb feeders. The lambs are too heavy for an economical feeding program and feeder prices are high, with packers competing for lambs carrying some finish.

8.16 Other Influences on Performance

Groups of feeder lambs are usually fairly uniform and therefore are not severely sorted. History of individual lambs is usually not known and lambs are seldom sorted according to sex, although these factors do influence feedlot performance.

Male lambs will gain faster in the feed lot than ewes, partly because

they are heavier at weaning time and upon entering the feed lot Though essentially all male lambs are castrated soon after birth and sold as wethers, considerable interest has developed in feeding young rams and marketing them for slaughter "intact" Such would avoid the shock, weight loss, and risk associated with castration Rams should gain slightly faster and produce leaner carcasses than wethers, so gains should be more efficient Since lambs (especially those from farm flocks) are slaughtered at a light weight and an early age, secondary sex characteristics have not developed and there is little evidence that carcass quality would be impaired Packers currently dock ram lambs $1 00 or more per cwt, regardless of weight Evidence to support this practice, especially in young lambs, is not available

Leaving male range lambs intact would probably be less practical because they are older when slaughtered The possibility exists, however, that certain hormones could be used to inhibit development of the secondary sex characteristics and the shock of castration could also be avoided here

Lambs born as singles are heavier at weaning than lambs born as twins or triplets especially in range flocks where feed supply and milk production are less, so singles probably will continue to perform better in the feed lot The same is true for lambs produced by mature ewes versus lambs born to two-year old ewes

Traits which have been studied as indicators of feed lot performance and careass merit in lambs are summarized in Table 8-5

Table 8 5 Approximate Correlations Showing Certain Traits in Feeders as Indicators of Feed Lot Performance or Carcass Merit in Lambs

Trait in feeder	Performance	Correlation coefficient
Initial weight on	Rate of gain	.05 to .10
Initial weight on	Carcass grade	.30 to .40
Feeder grade on	Rate of gain	0.00 to 05
Feeder grade on	Carcass grade	.30 to 40
Initial weight and feeder grade on	Rate of gain	05 to .10
Initial weight and feeder grade on	Carcass grade	30 to .40

*L. E Johnson, *Journal Animal Science* 3 224, 1944 Correlations involving rate of gain are based on all lambs being fed the same length of time

C Feeder Pigs

There is less movement of "feeders" in the swine industry than in the cattle and sheep industries, since sow herds must depend on a rather highly concentrated ration rather than on range grasses The areas where considerable high energy feed is grown and used for finishing all species are obvious locations for sow herds Sow farrowing on most farms has utilized excess farm labor before planting in the spring and between harvesting of small grains and corn in the fall

Only in recent years has hog production become greatly specialized, with feeder pigs being grown on one farm and finished on another. Such specialization is certainly not complete, but has been promoted by several factors. Increased competition and the need for specialization and lower production costs have been influential. Farrowing stalls, heat lamps, insulated housing, controlled temperature, and other beneficial items each require capital and must be kept busy in order to be profitable. Men with facilities, experience, and personal desire to work with sows and their young pigs have found it profitable to specialize. The term "pig hatchery" has been applied to some of these production units.

At the same time, many farmers have ample grain for feeding but have expanded or specialized in other branches of the farming operation, and lack labor, equipment, capital, or desire to farrow sows. Feeding weaned pigs to market weight requires relatively less labor, capital, and equipment, so many such farmers prefer to buy feeder pigs.

Several factors have delayed development of this specialization. Pigs are affected by and are carriers of many contagious and serious diseases. Farmers have naturally resisted bringing pigs from other premises onto their farms, especially if they might have been hauled in several different trucks and were routed through various markets. Also marketing costs for feeder pigs are high in relation to the value of the animal. Essentially as much labor, skill, and record keeping is involved in selling a 40-pound pig worth \$15, as in selling a 500-pound calf worth \$100 or a 700-pound yearling worth \$135.

8.17 Pig Producers and Dealers

Because of relatively high marketing costs, most feeder pigs are sold directly by producers to feeders, or are handled by dealers. Certain cooperative units have developed in feeder pig producing areas, such as Wisconsin. Relatively few feeder pigs are sold through central public markets, but a large number are sold through local auctions.

Nearly all feeder pigs sold by regular producers or dealers are sold soon after weaning, at about 40 pounds. Feeder pigs at many auctions, however, may range from under 40 to 150 pounds or more. Such heavy pigs are often referred to as "shoats."

8.18 Health

State laws usually require that pigs brought into the state be vaccinated and be certified as being in good health. Such laws do not control shipments within a state, however, so it is important that producers and dealers develop a reputation for selling only healthy, disease-free pigs.

Sanitation is extremely important, not only in farrowing houses, but also in scales, pens, and trucks occupied by pigs from a number of farms. Lack

Figure 8-5. Feeder pigs, sprayed for mange and lice and immunized for cholera, leave the yards of a feeder pig dealer. (*Successful Farming* Magazine)

of rigid sanitation procedures, or lack of scrutiny in purchase of disease-free breeding stock, has caused a number of "pig hatcheries" to fail. This was especially true in some started by men inexperienced in the risks of hog production. They held an "open house" in their farrowing unit to launch their business. Farmers, feed dealers, market men, and the general public attended, bringing a wide variety of vigorous disease organisms. Several such units were in business less than a year.

8.19 Appraisal

No official grades are used to group feeder pigs Purchasers are most concerned with health, reputation of grower or dealer, and uniformity in size.

Prices asked and paid for feeder pigs hinge primarily on price of slaughter hogs, because of the relatively short feeding period. Following are several guides commonly used.

1. Double market price of 220-pound slaughter hogs, per pound, up to 40 pounds and market price for each pound thereafter.
2. One third the value of a 220-pound slaughter hog, per head.
3.

Weight of pig	*Price per lb., compared to slaughter hogs*
40	1.8
50	1.7
60	1.6
70	1.5
80	1.45
90	1.4
100	1.35

The price of corn or grain sorghum and other ration ingredients, in comparison to the current and anticipated slaughter hog prices, should also be considered.

If pigs are healthy, there are few visual criteria that can be used to predict rate or efficiency of gain among feeder pigs. Reputation of the grower or dealer is much more important. Conformation, however, does give an indication of the *quality* of carcass that can be produced.

Barrow pigs will gain faster than gilts and will be slightly fatter at the same market weight, though there is usually little difference in feed efficiency. Feeders are not sold according to sex.

Some interest has developed recently in feeding boars, because they will gain faster, produce leaner carcasses, and gain more efficiently than either barrows or gilts (see Table 8-6). Besides consumer prejudice, researchers must also solve the problem of an offensive odor that is sometimes, though not usually, present in boar carcasses.

Table 8-6. Influence of Sex and Weight at Slaughter on Littermate Hogs*

Item	150 lbs.			200 lbs.		
	Gilts	Barrows	Boars	Gilts	Barrows	Boars
Number of animals	10	10	10	5	5	4
Dressing per cent	75.3	75.9	74.4	78.1	77.1	75.5
Backfat thickness, in.	1.4	1.4	1.2	1.8	1.8	1.5
Weight of "eye" muscle,[1] lbs.	2.2	2.1	2.3	2.9	2.2	3.0
Lean cuts, per cent of live wt.	39.3	39.3	40.3	39.5	36.2	40.2
Tenderness[2]	7.4	7.4	7.1	7.5	7.4	7.4
Flavor[3]	6.5	6.4	6.4	6.5	6.7	5.6

*V. R. Cahill et al., *J Animal Sci* 18 1482, 1959, and private communication.

[1] Longissimus dorsi.

[2] Score of 10 = very tender, 1 = very tough.

[3] Score of 9 = excellent, 1 = poor.

9

FEEDING FOR MEAT QUALITY

The consumer is the boss. In a "free" economy a potential purchaser is at liberty to accept or reject any product. The American housewife, who spends most of the money that is spent for food, can choose among a variety of high protein foods—beef, pork, lamb, chicken, turkey, cheese, eggs, fish—for the main dish in her menu. Faster transportation and more effective preservation, as well as better merchandising have made all these foods continually competitive in grocery markets. No longer are any of these items considered "seasonal" or peculiar to a certain area of the country.

Today's housewife in the United States begins her weekly food shopping trip with more money to spend than formerly. Yet she and her family do not desire more food. In fact because of lower caloric needs, etc., they eat less food quantity than the previous generation. This means she can afford *higher quality* foods. She can be more discriminating. She can also afford more "built in maid services," and is often willing to pay for having foods fully prepared for the pan or oven.

Though many aspects of meat quality are inherited to a degree, nutrition and management of meat animals can also exert a large influence. Total feed fed, levels of certain nutrients in the ration, length of the feeding period, use of certain feed additives, and age at slaughter can each influence the quality of meat at the retail counter.

These influences are often, but not always, reflected in the price a producer is paid for his animals. Though the effects of certain feeding programs may not be obvious when the animals are sold for slaughter, any effect on the quality of product the housewife buys will certainly influence future purchases or general demand.

9.1 What the Consumer Wants

What kind of meat does the American population desire? Tastes and preferences vary among people and in different sections of the country (Chapter 25). But there are some characteristics that are commonly desired in meat by most consumers.

We want a high proportion of *lean*. Excess fat on the outside of a roast

Figure 9-1. The American housewife has much freedom of choice when shopping for the main protein dish for the family dinner. (*Successful Farming* Magazine)

or steak, or heavy seams of fat between the muscle groups of a ham, are wasteful. Surplus fat on pork is more undesirable to the average consumer than on lamb or beef, probably because pork fat is softer.

The relative amount of lean in an animal carcass is highly influenced by heredity, so selection for leanness in breeding stock is worthwhile. Feeding, management, and age at market time can also have an effect, however.

Tenderness is important. People like to cut meat with a fork and chew it with ease. They will pay more for tenderloin than for round steak. Though tenderness is apparently associated with age of the animal at slaughter and fineness and texture of muscle fibers, recent evidence indicates other factors are important. The exact chemical structure of the protein molecules comprising lean muscle may be a factor, and there is some indication that tenderness is inherited to a degree.

Consumers are highly conscious of *flavor*. The "right" flavor is not clearly apparent. Some prefer a mild flavor, especially in lamb; others like a "distinct" flavor. Aroma is almost inseparable from flavor to the consumer and the "right" aroma is equally obscure. Though most consumers will tolerate considerable range in density of flavor and aroma, extremes in flavor and aroma must be avoided.

Meat that is *juicy* is more palatable. Studies with panels of tasters have shown that meat with considerable juiciness *seems* more *tender*, even though this may not actually be the case. This illustrates, though, that juici-

ness is important to the consumers' sense of satisfaction Finely dispersed bits of fat among the lean tissue (often called marbling) make the greatest contribution to juiciness Some fat, then, is highly desirable But it must be finely dispersed among the lean to give juiciness to every bite, rather than profusely laid down on the outside of the cut or muscle group

Shade and uniformity of color, size of cut, and other items may also be important to the consumer, consciously or subconsciously, and may exert considerable influence on her choices at the market

9 2 Carcass Grades

Grades are used to group meat carcasses according to quality Though many meat processors employ their own private grades and grading systems, the grades most uniformly used are those advanced by the Federal Grading Service of the USDA (Chapter 21)

Carcass grades serve a number of functions The consumer soon learns to identify a certain quality of meat with a particular grade Consumers know that meat bearing the official grading stamp of the USDA was graded by an impartial federal employee They know, too, that private grades applied to carcasses by packers must be applied with discrimination so that the housewife will develop and retain confidence in that companies' products

Many surveys have shown that most consumers are not closely familiar with individual grade names and the grade which should be applied to a certain carcass or cut This does not necessarily mean grades have little value On the contrary, evidence indicates housewives buy meat consistently from a certain market because it provides the quality she prefers consistently The retailer soon learns the importance of handling and promoting a certain grade The housewife needn't be able to match skills with a competent grader to show her dependence upon and the importance of a grading system

Many retailers handle only one grade of beef or lamb—usually USDA Choice, or a packer grade of corresponding quality Some retailers who serve a diverse income area such as a college community also provide a "budget" line of beef, which might grade USDA Standard Most pork leaves processing plants as trimmed, ungraded cuts, but retailers demand well muscled cuts with minimum fat.

Grouping carcasses into grades, and also into sex and weight groups, allows wholesalers and retailers to buy and sell by phone It also makes interpretation of market reports easier These and other topics concerning grading are further discussed in Chapter 21

Higher grades on beef and lamb carcasses indicate these carcasses have (1) a higher proportion of high priced wholesale cuts—loins, rounds, and ribs, and (2) higher quality within the cuts—more marbling, finer texture, brighter color, etc Because of the greater concern for lean pork, current

pork carcass grades are based largely on percentage of lean in the carcass. In general, higher grading pork carcasses have less backfat and a higher proportion of lean cuts—ham, loin, and shoulder.

It is important to realize that the carcass, *not the wholesale or retail cut,* is graded when USDA or most private systems are employed. Though there is some quality variation among locations or cuts within a carcass, consumers are generally aware of the degree of this variation, and there is little evidence that the variation would be greater in some carcasses than in others. It is also apparent that grading of individual cuts, by the USDA or a packer, would be extremely costly.

Understand, too, that grading is a *subjective* task. Though graders are well-trained, experienced, and supervised, the many characteristics which influence quality must be individually and collectively considered and the grader renders a subjective decision. Much research is now directed toward finding carcass traits that are highly correlated with quality and that can be quantitatively and objectively measured.

9.3 Length of Feeding Period

Because fattening of animals is a relatively slow process, length of the feeding period has a large influence on carcass quality. Cattle, lambs, or hogs on a high concentrate ration lay down more fat between muscles and on the outer surface of the carcass as time on feed progresses. The average thin feeder lamb must usually be fed a fattening ration 70 to 90 days before enough marbling has accumulated in the lean tissue to give desirable juiciness, flavor, and palatability. Four months on a high grain ration is usually considered *minimum* for yearling feeder steers to reach the low end of the choice grade. This may vary greatly depending on weight, breeding, and feed.

When high roughage rations are used for cattle and lambs, fattening does not proceed nearly as fast. This means that cattle on a high roughage ration usually can and should be fed longer.

With hogs a contrasting problem exists. Lean pork is preferred. But hogs can efficiently use only a high energy, concentrated ration and have a natural tendency to fatten at an early age. This means that for production and sale of high quality, preferred pork, hogs must be slaughtered at fairly light weights. Table 9-1 shows how the percentages of fat and lean in pork carcasses change at increasing slaughter weights.

All figures above show a definite and striking trend toward fatter carcasses from heavier hogs. Fatter hogs have a higher dressing percentage. In hog slaughter the fat remains on the carcass; only the hair, blood, viscera, and head are removed. The proportion of the cheaper, fat cuts increases tremendously, while the percentage of high-priced, lean cuts decreases. Not only is there a decrease in proportion of lean cuts, but the trimmed lean

Table 9 1 Carcass Quality of Pigs Slaughtered at Different Weights*

Live weight	150	175	200	225	250	300	400
Dressing per cent	73 7	78 9	78 3	79 3	78 6	83 2	83 7
Fat cuts per cent of carcass[1]	29 02	32 05	34 59	36 66	36 99	39 90	46 18
Lean cuts, per cent of carcass[2]	54 58	53 95	52 95	51 63	50 95	48 84	44 68
Ham, per cent of carcass	18 91	19 03	18 64	18 51	17 58	17 08	16.27
Per cent lean in the ham	66 24	65 06	63 17	60 23	61 11	60 60	52 63
Per cent of entire carcass							
Lean	51 52	48 55	45 00	43 48	43 04	41 08	34 34
Fat	32 40	37 38	41 79	44 33	44 90	47 70	55.27
Bone	10 45	9 33	8 79	7 58	7 56	7 09	5 86
Skin	5 30	4 45	4 16	4 20	4 17	3 88	4 19

*Wm J Loeffel *et al* *Nebraska Agr Exp Sta Bull 351* 1943
[1]Includes leaf lard fatback belly clear plate jowl and fat trim
[2]Includes loin ham Boston butt picnic and lean trim

cuts are *still fatter* and so lower quality, as indicated by percentage of lean in the ham The same is true for other lean cuts A true summarization is provided at the bottom of the table, showing the percentage of lean to be only two thirds as much in the carcasses from the 400-pound hogs as in the carcasses from the 150-pound hogs

Since a higher proportion of the heavier carcasses is fat, later gains on hogs obviously require much more energy so are more expensive And a lower quality product is produced!

What is the *ideal* market weight for hogs? This depends on several factors (1) Breeding—market hogs of genetically lean parents can be slaughtered at heavier weights and still yield lean carcasses (2) Supply and demand—if pork is scarce consumers are less discriminating and packers are less apt to dock heavy hogs But if pork is plentiful, heavy, fat hogs are severely discounted at the market (3) Production costs per pig—as with any other animal, production costs must be paid from the sale price of the animal If a litter is sold at heavy weights, more *total pounds* are sold so each pound sold needs to bear less of the production costs If it is a large litter each pig bears less of the cost of maintaining the sow and boar (4) Feed price—this interacts with supply and demand but if feed is cheap enough and pork valuable enough that each pound added to a hog will sell for more than it costs pigs will be fed to heavier weights

Obviously the ideal weight may mean two different things The ideal weight for most *profit* in a certain season may be markedly different than the ideal weight for top pork *quality*

9 4 Energy Level in the Ration

In animal growth the skeleton has first priority on nutrients consumed and absorbed (after maintenance needs are met), lean tissue ranks second,

and the animal fattens only if a surplus is available above the needs for the first two and maintenance. Energy level of the ration is therefore a major consideration in producing meat animals for slaughter. A slight restriction of energy intake will decrease fattening, though growth of skeleton and muscle tissue may continue. A further energy restriction will slow growth of muscle tissue but the skeleton may continue to increase in size. One is also familiar with the disproportionately large head and long legs on cattle subjected to semistarvation during prolonged drouth. This is because the skeleton has continued to grow almost normally, though growth of muscle and deposition of fat have been interrupted or almost stopped.

The classic research of McMeekan[1] is often cited to show the influence of energy on carcass composition. Pigs fed a liberal ration for 16 weeks, then fed a limited ration till slaughter time, had a high lean percentage in the carcass. Pigs fed the restricted ration during the first period, then the liberal ration, produced extremely fat carcasses. Liberal feeding early is apparently important, because the animal is actively growing and can produce considerable lean tissue. Later, after "growth" has slowed and fattening accelerates, restricting energy intake decreases fat deposition most.

Because leanness is so important in pork, some hog feeders have reduced energy intake by (1) hand feeding a restricted amount of ration—70 to 90 per cent of normal intake, (2) adding hay or other coarse, poorly digested roughage to a mixed ration that is self-fed, or (3) feeding on pasture. These techniques are generally impractical as long as the sole object is leaner carcasses. All methods delay marketing, meaning the hogs are maintained more days, more labor is used, risk continues, and the investment continues. Costs of gain may increase more than does carcass value. Hand feeding requires extra labor (though an automatic system could certainly be devised) and aggressive pigs still get a near-normal intake. When pigs are on pasture, more energy is used for movement so less is available for growth.

Since leanness can be changed so fast in hogs by selection and the effect of reducing energy intake is "temporary" (affects only this generation and not the next), it seems most practical to follow the feeding program that is most efficient and practical. If pasture can produce pork more economically than a dry-lot program, then pasture should naturally be used. But leanness can be most effectively and cheaply controlled by selection.

Surplus animal and plant fats have been used in swine and poultry rations because of their extreme energy potency and apparently high digestibility. As would be expected, adding five to 15 per cent fat to a swine ration increases fatness of the carcass, but the increase is small and could be offset easily by more rigid selection for leanness.

Proportion of energy in lamb finishing rations is influenced by two con-

[1] *J. Agr. Science* 30: 276, 387, 511; 31:1.

flicting factors Lambs need sufficient roughage to prevent overeating disease yet must be finished to grade choice at a relatively light weight Only limited quantities of extra fat can be used effectively in ruminant rations to increase energy content In such cases it is apparently important that a high quality roughage, such as alfalfa, be used

The ratio of concentrate to roughage varies greatly among cattle feeding programs and depends on weight and quality of cattle as well as prices of feeds Low quality cattle are usually fed little, if any, grain, since roughage is usually cheaper feed Consumers will not pay a premium for fat on low quality beef, and it doesn't pay to feed expensive concentrates to produce gain that will sell cheap It is better to invest grain in top quality feeders—cattle that can potentially grade choice or prime And even top quality feeders *need* grain to produce top quality carcasses

Table 9 2 shows the results of a Kansas test where calves of similar quality were fed different proportions of concentrate to roughage, their rations therefore containing different proportions of energy Carcass grades indicate cattle receiving 75 per cent grain graded much higher than those receiving only 50 per cent grain The carcasses carried more marbling in the meat and also more finish on the outside The extremely high concentrate ration, containing 83 per cent grain, produced carcasses of about the same quality as those produced on 75 per cent concentrate Though the 83 per cent grain ration was higher in proportion of energy, feed consumption was less, so daily energy intake was no greater (see Section 7 4) This and other evidence indicates that there is a "point of diminishing returns" as the proportion of concentrate in a ration is increased

Table 7-3 indicates the relative energy value of various concentrates Corn and grain sorghum are comparable Energy values of oats, barley, and some other concentrates do not seem much lower according to the values given But remember that about half the energy in a fattening ration is

Table 9 2 Ratio of Concentrate to Roughage for Fattening Steer Calves*

Per cent grain sorghum in ration	50 0	75 0	83 0
Number of calves	10	10	10
Initial weight, lbs	502 00	503 00	505 00
Final weight, lbs	934 00	949 00	933 00
Av daily gain lbs	2 13	2 20	2 10
Av daily feed, lbs	23 25	20 84	19 38
Alfalfa, lbs	12 22	6 68	5 08
Grain sorghum, lbs	11 03	14 18	14 30
Feed per 100 lbs gain lbs	1,093 00	948 00	919 00
Dressing per cent	58 60	60 00	60 30
Av carcass grade[1]	3 90	5 40	5 00

*D Richardson *et al* *Kansas Agr Exp Sta Circ 335* p 32 1956

[1]Score of 6 = top choice 5 = av choice 4 low choice and 3 = top good

used for maintenance. Of the remainder, first priority goes to skeletal growth, second is muscle growth, and *only* that remaining is available for deposition of fatty tissue among the muscle fibers and bundles. So the *fattening* value of such feeds may differ *markedly.*

9.5 Protein Level

A higher protein ration, above the levels "adequate" for normal growth, produces leaner carcasses. Lean tissue is composed primarily of protein and water. Animals cannot produce protein for lean tissue from other nutrients. The increase in leanness resulting from extra protein is not large, but is *consistent* (see Table 9-3).

Table 9-3. Influence of Protein Level on Pork Carcass Leanness*

Protein level, percentage	10	12	14	16	18	20
Live probe, in.	1.6	1.5	1.5	1.4	1.4	1.3
Carcass backfat thickness, in.	1.6	1.6	1.6	1.6	1.5	1.5
Specific gravity[1]	1.0183	1.0229	1.0258	1.0253	1.0286	1.0296
Per cent lean cuts	58.9	59.9	59.7	60.2	60.6	61.0
Area of loin muscle, sq. in.	3.4	3.5	3.7	3.7	3.9	3.6

*G. C., Ashton *et al.*, *J Animal Sci.* 14 82, 1955.

[1] Since fat is lighter than water, carcasses are actually weighed in water, then specific gravity is calculated. Carcasses that are fatter have a greater tendency to float, therefore a lower specific gravity.

In hogs the increased *cost* of a high protein ration is usually greater than is the increased *value* of the carcass. In fact, hogs fed 20 per cent protein are not enough leaner than hogs fed 12 per cent protein, that the average packer buyer could visually detect the difference.

Similar effects have been observed in cattle and lambs but the influence is not usually as large as in hogs. Because of the relatively high cost of high protein feeds, it is usually practical to feed the level of protein that will produce the most *economical* gains.

9.6 Specific Feeds

Acorns and raw soybeans are popularly known to produce soft, oily pork carcasses, if pigs have access to them until shortly before slaughter. Acorns contain about ten per cent oil and soybeans about 18 per cent. These plant oils are composed of unsaturated fatty acids, so are liquid at room temperature. When a pig consumes acorns or soybeans, the oil is released from the feed by digestion in the small intestine, absorbed into the circulatory system, and carried to the cells for storage with *very little* chemical change. This deposited "fat" is therefore considerably softer than typical pork fat.

If these oily feeds are removed from the ration about 45 days before hogs are slaughtered, the fat seems to "firm up" and good quality carcasses can be produced. This is because the soft fat previously deposited has been mobilized from the original storage cells, metabolized or chemically changed

by the pig to typical pork fat and redeposited This is a normal process, but the time lapse after feeding the oily feeds is necessary before slaughter

Corn geneticists have developed high oil strains of corn, specifically for production of domestic corn oil, but such corn would also be a high-energy feed for livestock Hogs fed high oil corn produce carcasses with slightly softer fat when measured by precision techniques, but the effect would not be noticeable to the average consumer

Processed garbage fed to hogs sometimes produces relatively soft carcasses, unless the hogs are hardened on grain for several weeks before slaughter Though oil content of garbage varies, salad oils and dressings, lettuce, and some other vegetables contribute considerably

The specific feeds discussed above are of little concern in beef or lamb quality because the feeds are seldom used in ruminant rations, or are used at low enough levels that any effect is not obvious Also, since any unsaturated fatty acids are apparently hydrogenated (made saturated) in the rumen, the fat deposited tends to be harder

Some current research has been directed toward feeding sugar to meat animals before slaughter to increase the dressing percentage, decrease carcass shrink in the cooler, or improve the color of lean after slaughter The value of this practice has not been fully substantiated

9 7 Feed Additives

Antibiotics included in livestock and poultry rations do not cause a marked change in meat quality Any change which might be caused by the antibiotic would be an indirect effect, resulting from improved health, more rapid gains, etc When antibiotics were first popularly used in swine feeding a belief that fatter carcasses were produced prevailed Research indicated that if there was an increase in fatness it was slight and not consistently measurable

Stilbestrol was first used in poultry feeding (implanted under the skin) to improve carcass quality This synthetic estrogen produced broiler carcasses that were fatter and more desirable in appearance to the consumers

When recommended levels of stilbestrol are included in cattle and lamb *rations* to increase gains and feed efficiency, there is little apparent effect on carcass quality Because the compound causes a slight relaxation and drooping of the pelvic bones, the 'tail head' appears higher on carcasses from cattle fed stilbestrol, and the rump does not appear as wide and muscular Though this effect is apparent, there *may* be no *real* influence on carcass quality

When *excess* levels of stilbestrol are fed to cattle or lambs, carcasses generally grade lower, have less muscular rounds or legs, have more water retained in the tissues, and have less marbling Recent studies[3] have also

[2] D C Acker *et al* Iowa Agr Exp Sta, unpublished data

[3] E Nelson McIntosh D C Acker and E A Kline, *J Agr and Food Chem* 9 418 1961

indicated that stilbestrol fed to lambs, even at recommended levels, causes an increase in certain connective tissue components of the muscle. Though connective tissue is thought to be related to tenderness, no effect was noted by panel members who sampled cuts from these carcasses.

Metabolism studies indicate stilbestrol increases protein retention in the animal body. But there is little evidence to show this extra protein retained builds more muscle; it might be used for other "protein" tissues—skin, connective tissue, wool, hair, etc.

Use of stilbestrol and some other additives in livestock feeding comes under scrutiny of the Food and Drug Administration because of a Food Additives bill passed in 1959 by the 85th Congress, and because of other legislation.

Other "synthetic hormone" compounds are known to have more marked effects on carcass quality. A combination of 250 mg. progesterone and 10 mg. estradiol implanted in lambs greatly lowered carcass quality in research at three experiment stations. Pelts were very difficult to remove from these lambs at slaughter, apparently because of increased connective tissue between the pelt and carcass. Some of this tissue remained on the carcasses. The carcasses were less blocky, graded much lower according to USDA standards, and shrank more in the cooler, indicating the tissue probably contained more water at slaughter.

A variety of other compounds have been experimentally used in feeding all classes of livestock. When feeders of livestock read and appraise results of such research they should look closely for adequate information concerning effect on meat quality. Only with such information can the value of the material be fully assessed.

Thiouracil and other compounds which inhibit or suppress the activity of the thyroid gland have been tried in several classes of livestock to improve performance and carcass quality. The theory was that these compounds would slow activity and rate of metabolism, and the steer, lamb, or pig would be quieter in the feed lot. Less energy would be used for "maintenance," more for fattening, and the animal would finish quicker. These compounds have not been commercially used, however. Levels that have been tested usually exert no effect, or cause the animal to be so sluggish that feed consumption goes down.

Of current interest is the use of antioxidants in swine rations to help stabilize pork fat, preventing rancidity. Pork fat is softer and much more subject to rancidity than beef or lamb fat.

9.8 Pelleted Feeds

Cattle and lamb feeders who have switched to pelleted rations to mechanize feeding, insure uniform consumption, and reduce storage space, have noted that animals often go on concentrate feed faster and produce slightly higher quality carcasses. This effect is especially true in lambs where quick finishing at light weights is extremely important (Table 9-4).

Table 9-4 Effect of Pelleting Rations for Lambs*

	1953		1954		1955	
	Non-pelleted	Pelleted	Non-pelleted	Pelleted	Non-pelleted	Pelleted
Number of lambs	37	37	31	31	35	40
Initial weight, lbs	61 70	62 60	63 00	94 70	96 00	65 10
Av daily gain, lbs	0 45	0 49	0 40	0 44	0 34	0 41
Feed per lb gain, lbs	8 56	9 05	9 20	9 0	9 93	8 55[1]
Dressing per cent	50 60	50 70	51 30	51 90	50 90	51.80
Carcass grade						
U.S choice	20	29	26	27	14[1]	19[1]
U S good	17	9	15	14	21[1]	21[1]

*R L Noble *et al* *Oklahoma Agr Exp Sta Misc Pub 31 34 and 43*
[1] Estimated from figures given

Fatter lambs, which grade higher, will have a higher dressing percentage because the fat is part of the carcass, and because they are more symmetrical, the percentage of pelt, shank, etc , is probably less

The level of roughage in cattle or lamb rations influences the value to be gained by pelleting More benefit is derived from pelleting high roughage rations

9.9 Pasture

The main effect of most pasture is to reduce energy intake and thereby reduce fattening rate of any species Rate of gain is usually reduced in comparison to dry lot feeding of a concentrated ration, but the amount of reduction is influenced by the quality and amount of pasture forage Some energy is also lost from production because the animals use energy roaming the pasture

If forage is 'washy"—extremely high in water content—some animals can t eat enough to obtain sufficient energy for rapid growth and fattening Supplemental concentrates and/or dry hay must be provided Legumes are generally lower in energy than grasses, so contribute less to fattening Legumes do, however, supply more of the needed protein, so a good grass-legume mixture provides excellent pasture Such a mixture also often yields more, in addition to providing a more 'balanced' diet

Pigs consume relatively little pasture, but if good quality alfalfa or similar pasture is available, this can go far in supplying protein needs Naturally, pasture raised pigs will be slightly leaner, but the economy of this type of production versus feeding in dry lot and growing corn or sorghum on the land must be closely checked

Cattle slaughtered directly from pasture may carry a more yellow colored fat especially in early summer when grasses have been lush This yellow color is caused by yellow pigments—carotene and others—in the forage They are not obvious in growing forage because they are masked by the green chlorophyl This yellow color does not influence flavor, aroma, nutri

tional value, or any other quality aspect. Color of fat is not mentioned in USDA grading standards. However, some consumers, and therefore some retailers, object to this yellow color.

There are individual and breed differences in the ability of animals to convert these yellow pigments to colorless compounds after consumption, so variation exists among carcasses of animals which have all been on pasture. The pigments are "fat-soluble," so are carried and stored in the fat. A more golden or yellow-tinged milk from some breeds of dairy cattle has the same cause.

10

THE BUSINESS OF FEEDING

Livestock feeders are in business to make a profit In normal years they expect a monetary return for labor, home-raised feed, capital, management ability, and risk they assume

Since livestock feeding is often only a part of a general farming operation and hours of labor invested in the particular feeding enterprise are not usually recorded, it is difficult to calculate an hourly return for labor In specialized feeding operations, however, the exact amount of labor can be easily determined Feeders often jokingly comment that they "ignore labor costs if they expect to make a profit" On a family farm where other enterprises are profitable this may be *feasible*, though not *practical* In a specialized feed lot operation such an attitude is not feasible! Labor costs have risen much faster in recent years than most other farm costs (Figure 10-1)

Merely to receive a return for labor is not sufficient To justify continuance of the feeding operation in well managed agriculture the return to labor must be *greater* in that particular enterprise than in some alternative project

Years of records from Corn Belt farms have shown that home grown grains and roughages are consistently sold for a higher price *through livestock* than if sold direct on a cash market In some years and with certain livestock feeding programs the return per bushel of corn or per ton of hay is sometimes *double* when no return is calculated for labor or management Of course, this type of calculation would be realistic *only* if there were no alternative use for labor and management ability

Much money is invested in capital items—harvested feed, lots, buildings, feed bins, bunks, feeding equipment, etc—as well as in the animals The feeding operation should return the interest on money borrowed to finance the operation, and perhaps some for the *risk* the feeder has assumed Even if the investment is not borrowed, the feeder should expect and receive the same rate of return

Management ability is usually the key to livestock profits The ability to buy and sell—the right animals, at the right time, at the right place, and at the best possible price—is probably the biggest part of management Selection and formulation of economical, adequate rations is likewise important

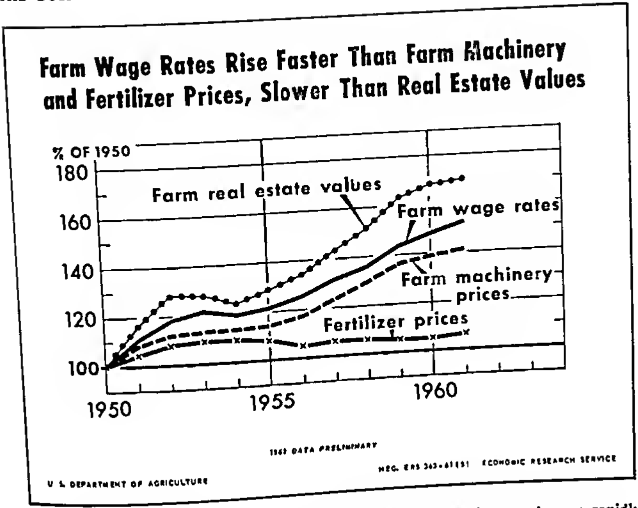


Figure 10-1. Changes in farm cost rates. Note labor cost has increased more rapidly than cost of power and machinery. This means the relative advantage of replacing labor with power equipment on farms may have increased in recent years.

So are sanitation, disease control, sufficient shelter, and a variety of other items. Stresses which might impair performance must be *avoided* rather than cured.

Any livestock feeder must consistently compare his returns for labor, feed, and management with the return he might expect for these items in alternative enterprises.

10.1 Location

Though distribution of livestock in various areas of the United States was discussed in Chapter 1, the economic impact of animal adaptation for the *individual* feeder was not stressed. In arid climates feed lots and pens are usually dry. Since disease organisms don't reproduce and spread as rapidly in a dry environment, diseases are less prevalent and less costly to feeding operations. In cattle on feed there is less foot rot and there are fewer internal parasites which normally would compete with the host for nutrients and cut down feed efficiency.

Humid areas are ideal for proliferation of disease organisms and parasites. Though the diseases can be counteracted and controlled, preventive

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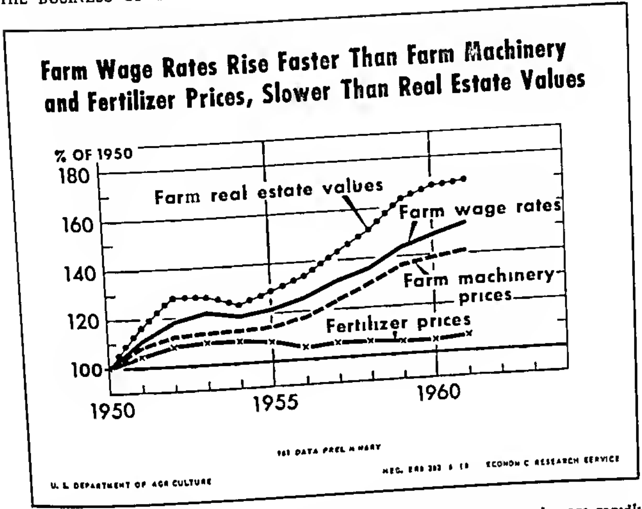

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Humid areas are ideal for proliferation of disease organisms and parasites Though the diseases can be counteracted and controlled, preventive

measures—concrete floors, ventilation, careful cleaning, and disinfecting—cost money

Temperature extremes are costly in feeding cattle, lambs, hogs, or poultry In hot weather feed consumption goes down, so less of the nutrients consumed go to gain Prolonged hot spells can be very costly, and air conditioning is expensive, though some cooling can be effected without great cost (Chapter 12) In very cold weather animals (especially non ruminants) use up extra energy just to keep warm This may sometimes be cheaper than providing artificial heat, but insulated buildings are often a good investment for hogs, poultry, calves, and lambs

Proximity to feed supply is important, *especially* with ruminants which usually receive a *bulky* ration and also require more pounds of feed per pound of gain Although movement of feed for any species represents an expense, examples could be given where it is practical to haul some of the ration ingredients many miles so that a broiler, turkey, or swine feeding operation could be located in a favorable, arid region or where labor is especially cheap

Nearness to markets and consumption centers is a consideration, but not as important as formerly A number of factors have caused meat processors to move closer to producing areas Speedier transportation and refrigeration allow movement of perishable carcasses or cuts long distances without spoilage When animals are processed near where they are fed, fewer pounds have to be transported, and the meat can be packed very compactly in a railroad car or truck A large number of packers are scattered through the feeding areas of the Midwest Packing plants have been built adjacent to large commercial cattle feed yards in Colorado, Texas, and other states

10 2 Financing

Capital is needed for four general functions (1) *Relatively permanent investments* in land, buildings, pens, bunks, and other items can be am mortized over a period of years because they depreciate slowly Though the feeder needs a fair interest rate return on this type of investment, he needn't repay the capital the first year (2) *Feed* is a major expense in most feed ing operations, especially with broilers, turkeys, and swine The poult, chick, or pig is small so not costly, and feed is used to increase the initial weight five or more times For example, for a feeder pig bought at 35 or 40 pounds and fed till slaughter at 210 pounds, feed represents a larger proportion of the total investment in the finished animal than initial cost, facilities, or other items (3) *Cost of the feeder* is a relatively greater ex pense in cattle and lamb feeding When feeder calves are purchased at 450 pounds, fed, then sold for slaughter at 950 to 1000 pounds, half the sale price is often used to repay the loan transacted to purchase the feeders Cost of the feeder is even greater, relatively, with lambs, where feeders are

bought at 65 to 70 pounds and sold for slaughter at about 100 pounds Another example would be heavy cattle bought for just a short feed before slaughter (4) *Operating expenses*—power for grinding, mixing, and feeding, veterinary bills, normal death loss, transportation, and marketing costs —must be considered Though they usually represent a small percentage of total investment, they still "add up" and must be paid

Few feeders finance their own operations completely without need for credit Most depend on local banks and lending agencies for financing Extension of credit by these lending agencies varies, depending on reputation and experience of the feeder, financial soundness and responsibility, the outlook for a good or poor "feeding season," and other factors In a typical cattle feeding operation involving 50 to 200 head, banks may loan enough money to buy the cattle, providing the feeder has enough *feed* and capital for *operating expenses* Deviations from this example are so numerous and vast that space does not permit a thorough discussion

Feed companies, which furnish complete rations or supplements for home grown feeds, often extend credit to customers Hatcheries may sell broilers or turkey poults for feeding and not demand payment until the birds are sold Some companies go further, selling equipment for the feeding operation on a deferred payment plan Interest must naturally be charged for such extension of credit, whether apparent to the feeder or "hidden" in the stated price Feeders should expect to pay a *higher* interest rate in such situations since they have not invested greatly of their own capital and those who have extended the credit are carrying most or all of the risk These types of credit programs are discussed further in Section 10 8

A good manager makes *good investments* Though he may be financially sound and capital or credit easily available, he spends the money judiciously He knows where and when to spend money to *make* money The purchase of good feeders that will perform well, the choice of a supplement or ration that will do the job economically, and vaccination, when warranted, for shipping fever, cholera, or overeating disease are examples He also knows where and when he should *not* spend money Many examples could be cited, including feeding more supplement than is beneficial, building an expensive brick barn when a pole shed will provide optimum shelter, or buying labor-saving equipment when there is no other use for the labor "saved"

10.3 Costs of Gains

Because feed is a major expense in all feeding operations, factors which influence efficiency of feed utilization may determine profit or loss Variations in inherited ability to gain efficiently were illustrated in Sections 8 4 and 8 5 Other important factors are cost of feed preparation (harvesting,

shelling, grinding, mixing and/or pelleting), weight and relative fatness of animals, feed wastage, and certain environmental stresses such as disease, parasites, or extreme temperatures

Feeding cattle on pasture eliminates the need for harvesting forage Though the cattle expend some extra energy in grazing, this may be offset by elimination of the harvesting cost In other cases, however, feeders have found it practical to chop forage daily and haul it to the lot for feeding This is done not only for fattening cattle, but also for dairy heifers and cows Though the daily task of chopping requires considerable extra labor, annual forage yields are usually much higher because the cattle have not trampled down the forage The higher palatability of the freshly chopped forage may justify the daily chopping, versus harvesting the entire crop at one time and storing it in a silo or barn

Cost of feed preparation can vary considerably, depending on volume, power source, planning of operations, and efficiency of equipment For example, it may not be worthwhile to grind corn for steers on feed if the corn must be scooped by hand from the crib into a tractor-powered grinder, and later scooped into the bunk This would be especially true if there were light hogs following the cattle in the feed lot to salvage some of the corn that "came through" undigested If, however, the corn could flow by gravity into a meter fed grinder (requiring no attendant) and be blown from there to storage adjacent to the feed bunks, grinding might be entirely practical

Research at a number of experiment stations over a 40-year period has repeatedly shown less corn is needed per pound of gain if it is shelled, and usually additional corn is saved by grinding and mixing with other ingredients Cost of shelling, grinding, and mixing should be considered, however, *in relation to* the cost of corn More thorough preparation to insure better utilization is most practical when grain is expensive

Heavier and fatter animals nearly always produce more costly gains (Table 10 1) Note that the average daily gain reached a peak at about 175 pounds, then gradually declined Daily feed consumption continued high however, so that more feed was consumed per pound of gain There are two main reasons (1) The heavier animals need more feed and energy for maintenance—for movement, drinking, digesting the bigger volume of feed, etc (2) Each additional pound of increased weight in the heavier hogs contains more *fat* Since fat contains about two and one quarter times as much energy per pound as protein or carbohydrate, more energy is needed to *form* fatty tissue in an animal than to form lean, protein tissue Also, fatty tissue is mostly fat, while lean muscle tissue contains considerable *water* in addition to protein

Results of several years operation of the Ohio swine evaluation station indicate lean hogs gain more efficiently During one year the 423 pairs of pigs whose carcasses were lean enough to be classed as "superior" con

Table 10-1. Gains, Feed Consumption, and Feed Efficiency of Pigs by twenty-five-pound Increments*

Weight increment, lbs.	Av. daily gain, lbs.	Av. daily consumption, lbs.	Feed/cwt. gain, lbs.
75-100	1.00	3.24	323
100-125	1.39	4.94	357
125-150	1.47	5.58	399
150-175	1.73	7.20	416
175-200	1.60	7.92	493
200-225	0.94	5.48	583
225-250	1.60	7.02	437
250-275	1.64	7.35	446
275-300	1.55	8.47	546
300-325	1.15	7.52	653
325-350	1.12	6.81	579
350-375	1.03	6.37	617
375-400	1.13	6.57	582

*Wm. J. Loeffel *et al.*, *Agr Exp Sta Bull 351*, 1943. *Nebraska*. Deviations from trends are normal and may be due to weather, time of day animals were weighed, or other factors.

sumed 337 pounds of feed per 100 pounds of gain. Pigs whose carcasses were too fat to provide for certification of their litter-mate boars gained as fast, on the average, but required 350 pounds of feed per 100 pounds of gain. Such a difference has been noted at a number of swine testing stations. During the winter testing seasons the difference in feed efficiency between lean and fat hogs is usually *not so large* as in the summer season. Apparently the extra fat provides beneficial insulation, so the fat pig expends less energy to keep warm.

10.4 Margin

The term "margin" is not synonymous with profit in livestock feeding. Instead, margin is defined as the difference between the purchase price of the feeder per pound or per cwt. (hundred pounds) and the sale price of the finished animal ready for slaughter. For example, if a 700-pound steer is purchased for $25 per cwt., fed, then sold for slaughter at $27 per cwt., the margin is $2 per cwt. In effect, the feeder *raised the value* of the pounds he bought. The margin of $2 per cwt. applied to the 700 pounds purchased so contributed a *total* of $14 to potential profit that might result from the feeding operation.

Any additional profit would come from producing gain at a lower cost per pound than the sale price. In this case, if the steer gained 400 pounds during the feeding period (being slaughtered at 1100 pounds) at a cost of 22 cents per pound of gain, the profit from *gain* would be $20. The 400 pounds of gain was sold at five cents higher than the cost of producing it. Total profit for the feeding operation of this one animal (ignoring marketing, transportation, etc.,) would therefore be $34, $14 from "margin" and $20 from "gain."

Take a look at a second example A lamb feeder near Roswell, New Mexico bought 2000 feeder lambs averaging 60 pounds for 19 cents per pound He sold them at 105 pounds, average, after about 80 days on feed, for 20 5 cents per pound Here the margin was 1 5 cents per pound and applied to the 60 pounds purchased So the *total* margin realized on the 2000 lambs was $1800

Margin can also be negative, deducting from profit or contributing to loss in a feeding operation In fact, when feeding pigs or especially light calves, a negative margin is expected In these cases the pounds bought, in relation to the pounds sold, is much less So a positive margin would not be as helpful and a negative margin not as serious The animals are fed a relatively long time—calves are usually fed until their weight is more than doubled and the feeder pigs' weight is increased four to five times All this means that the *cost of gain* in relation to the selling price is much *more* important than is the *feeder price* in relation to the selling price

Remember, too that the price of a light feeder per pound *must* logically be *more* than the price of a heavy feeder, assuming comparable quality This is because the total costs of producing the feeder—raising and maintaining the cow (or ewe or sow), the sire, labor, marketing expense, etc , —must be met by fewer pounds sold In fact, hog men often feel a *fair* price for 35 pound to 40 pound feeder pigs is *double* market price of slaughter hogs per pound (Section 8 19)

Even with a negative margin the entire feeding operation can still be profitable with hogs or light cattle Because the animals are *light*, they will be relatively *efficient* in feed utilization and gains can be cheap Also, feeder calves can utilize much cheap forage that might otherwise be wasted After purchase in the fall calves are often turned out to corn stalk and grain stubble fields until "snow flies," so their early gains can be especially cheap

A young farmer in Lancaster County, Pennsylvania, bought a load of 500 pound steer calves for $31 per cwt They were "wintered' on oat stubble and new seeding then full fed on corn silage, and were eventually finished on corn They sold at 900 pounds for $29 per cwt The negative margin of $2 per cwt on the 500 pounds purchased contributed a $10 'loss " The young feeder fed an economical ration, however, and gain cost only 21 cents per pound ($21 per cwt) Profit from gain—$32 per animal —minus the $10 negative margin per head, figures $22 *net profit* per head (again ignoring miscellaneous expenses)

Figure 10 2 provides opportunity to calculate margin *needed* in certain cattle feeding operations, depending on cost, weight, and grade of feeders, as well as on price of feed This is merely a guide, but does show how these factors influence the margin needed with typical feeding programs Naturally, more efficient feed utilization than assumed here would lower the margin required for profit

HOW TO FIGURE SELLING MARGIN NEEDED IN FEEDING

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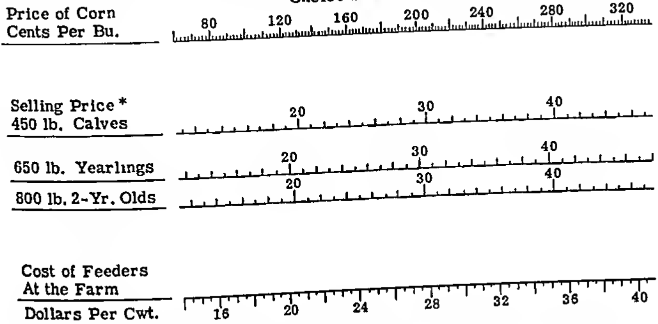
METHOD: Lay a ruler across the chart for the grade of cattle you are feeding. Place the edge on the cost of feeders and on the cost of corn. The point where the ruler crosses the center line shows the selling price needed to pay feed costs, interest on cost of feeders and normal death risk.
OTHER FEEDS. In these charts, protein, hay and pasture costs have been figured at their normal relation to corn prices

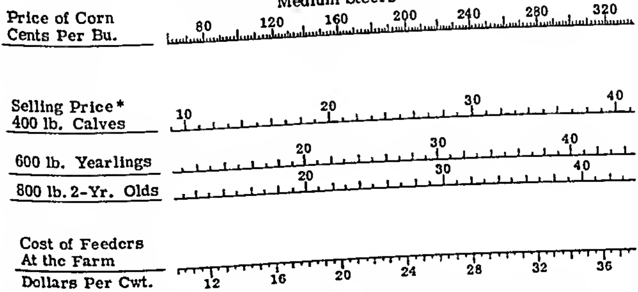
Choice Steers



*Needed to pay feed, interest and death risk.

FEEDING PERIOD Calves fed to gain 550 pounds in about 10 months. Yearlings fed to gain 400 pounds in about 7 months. Two-year-olds fed to gain 350 pounds in about 5½ months

Medium Steers



*Needed to pay feed, interest and death risk.

FEEDING PERIOD Calves fed to gain 470 pounds in about 9 months. Yearlings fed to gain 300 pounds in about 6 months. Two-year-olds fed to gain 250 pounds in about 5 months.

Figure 10-2. How to figure the selling price that will be necessary to "break even" feeding cattle Necessary selling price minus purchase price equals necessary margin (Iowa State University)

10 5 Performance Knowledge

Most good managers know what it costs to produce their product, whether the product be baseballs, automobiles, washing machines, or wieners They can show how much each ingredient or piece costs, the amount and quality of labor needed for each manufacturing step, and the percentage rejected at the end of the production line

Because feed is a major cost in livestock production, knowing the pounds used and total cost is worthwhile Great variations which exist in feed efficiency of animals have been referred to in earlier sections Only by recording feed consumption, and comparing it to gains, can the feeder *know* whether his animals are efficient or inefficient A scales is a wise and profitable investment on most livestock farms

The best records are usually the simplest and easiest to keep, because they are more apt to *be* kept Feeders can simplify record keeping systems by knowing the capacity of wagons, bins, and feeders, by calibrating them in 10-pound or 100-pound increments, and by trying to handle all feed in batches that are multiples of 100 pounds This simplifies calculations and helps prevent mistakes

Records disclosing death losses—date and cause, veterinary expenses, and other items—are worthwhile

Many feeders routinely weigh feeder livestock when they arrive at the farm and finished cattle, lambs, or hogs before they are loaded to head for market They soon gain an appreciation of shrink that occurs in transit, the difference in shrink between the feed lot and various destinations, and certain factors which influence shrink

10 6 Value of Manure

A by product of any livestock feeding operation is the manure Table 10-2 shows the approximate pounds of critical soil nutrients contained in

Table 10 2. Approximate Soil Nutrients Per Ton of Manure from Different Species

Species	Nitrogen (N) lbs	Phosphoric Acid (P_2O_5) lbs	Potash (K_2O) lbs	Tons manure produced per year per 1 000 lbs weight
Horse	13 2	5 1	12 1	12.00
Cow	11 4	3 1	9 9	15.00
Pig	9 9	6 7	9 3	18.25
Sheep	115 8	6 7	18 0	9.75
Steer	15 0	6 0	8 0	9 00
Hen	21 0	16 4	10 2	4.5

average manure, including solid, liquid, and bedding. There is naturally much variation in fertilizing nutrients contained in manure, but the figures do indicate it contains real dollar value.

Soil nutrients are present in the manure because digestion and absorption are not *complete* and some absorbed elements, especially nitrogen, are excreted via the urine. Figure 10-3 shows the approximate proportions of nitrogen (N), phosphorus (P), and potassium (K) that are retained in livestock tissues when 1,000 bushels of corn are fed, versus the proportion excreted in the feces and urine.

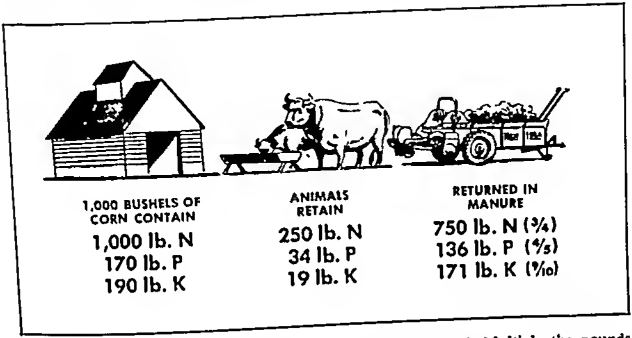


Figure 10-3. Nutrients retained and excreted when corn is fed. Multiply the pounds of each nutrient by the price of that nutrient from commercial fertilizer sources. Such calculations often indicate manure from a bushel of corn contains 10 to 12 cents worth of nutrients. Cost of spreading the manure must be considered, however. (New Idea Farm Equipment Co.)

There is, of course, considerable labor and expense involved in hauling and spreading manure. Also, some elements may be lost if considerable time elapses before the manure is spread on the fields.

Soil nutrients can usually be provided more cheaply in the form of commercial fertilizer than by manure. This has encouraged numerous livestock raisers to build "lagoons" or "sludge pits" where manure decomposes under water and the cost of spreading is eliminated (Figure 10-4).

Manure might also be handled as in many sewage disposal plants—decomposed by bacteria in an air-tight tank with the resulting production of methane gas. The gas can be used as fuel, for heating the livestock buildings or for other functions. The sludge, removed periodically from the decomposition tank, is a concentrated form of fertilizer. It contains essentially all the nitrogen, phosphorus, and potassium, but is tremendously reduced in volume and weight.

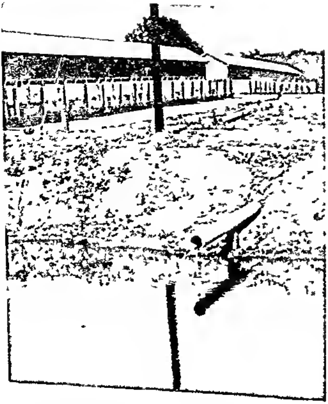


Figure 10-4. A manure lagoon for a large hog feeding operation in the Midwest (*National Hog Farmer*)

Organic matter, normally supplied by manure, is important for maintaining good soil structure. This can be supplied, however, by plowing under larger quantities of crop aftermath—corn stalks, legumes, etc.—that can result from larger yields

Manure should not be spread on pastures currently being grazed; it will reduce forage consumption.

10.7 Specialization

Advantages of specialization in almost any agricultural enterprise have become obvious in recent years Naturally, there are disadvantages, but many of these are currently being overshadowed Some of the reasons for increased specialization are given below.

Competition is keen Though our population has grown rapidly, farm production has increased faster. This means ample food and not exceptionally high market prices Producers are operating on narrow margins Each farmer or feeder tries to cut production costs and become more efficient so his enterprises can be profitable at the prices prevailing

There is *more technical "know-how"* connected with each enterprise. Many alternative management techniques must be considered Cattle feeders, for example, are concerned with such choices as (1) handling forage as hay (loose, chopped, or baled) or as silage; (2) handling corn as grain (shelled or ear, high-moisture or dry) or as silage; (3) feeding or implanting stilbestrol, including molasses, sulfur, Vitamin A, urea, enzymes, tran-

quilizers, and/or goitrogens in their feeds; (4) feeding rations by hand, self-feeding free-choice, mixing, or pelleting; (5) length of feeding; and (6) selling on a live basis or by carcass grade and/or yield. Hog raisers and lamb feeders are confronted with as wide a variety of problems—some practical and some *highly technical.*

It is important to know not only that certain of the above alternatives exist but also *when* and *if* an alternative should be followed in a particular livestock operation. Unfortunately not all that is printed or said about new developments is *true,* and much that is true in *certain* circumstances will not be true in others. A competent manager must be able to sort out that which he can use *profitably.*

We have learned to combat and control stresses, such as temperature extremes, injury, and certain diseases with heat lamps, farrowing crates, sheltered feed bunks, artificially cooled or heated and fully insulated buildings, concrete floors, pressure water systems, steam cleaners, and flame throwers. But since such equipment is collectively expensive, it must be used to justify its cost.

There is emphasis on saving time and labor, but labor-saving equipment *costs money.* Farmers and feeders justifiably want to work fewer hours. To keep good hired labor, a shorter work week has become essential. But to justify investment in expensive labor-saving equipment, this equipment must be *kept busy.* This encourages specialization and larger units.

There is competition in *product quality.* Consumers are more discriminating and are willing to pay for high quality items. They will avoid over-fat pork, heavy lamb cuts, and lower qualities of beef. Producers and

Figure 10-5. A mechanized cattle feeding operation in southwestern Iowa The glass-lined silos hold grain or forage, wet or dry. Supplements and premixes are stored in the white building, above grinder-mixer which supplies the auger in the tube (A. O Smith Corp)

processors who specialize *can* pay more attention to quality A hog raiser with 100 sows, small groups farrowing periodically, *can afford to pay* much more for a good meat type boar than can a farmer who breeds only 10 sows twice a year Raisers become better acquainted with the type of animals that can produce high quality carcasses, and can afford to pay more attention to feeding and management influences

10.8 Contract Growing and Feeding

Earlier in this chapter it was pointed out that a livestock grower or feeder should logically expect a monetary return for his labor, home raised feed, capital management ability, and the risk he assumes in his operations If feed is considered a part of the capital, it is evident that the same kinds of returns are expected here as in *any* business

If any other party—feed company, hatchery, packer, or farm manager—provides one or several of the above essential items, they should expect and receive an equitable monetary return for the items they provide Contract growing and feeding of livestock—also called vertical integration—involves this economic principle

Probably hundreds of different type contract arrangements exist, but one hypothetical example will be given here A 25 year-old farmer in eastern Kansas is married and has two children He rents a good half-section of land that is high in fertility, so he can raise plenty of grain and forage He has a good line of machinery but owes heavily on it He wants to raise hogs (because he has learned feed can usually be sold for more through livestock and because the farming operation will not keep him fully employed during the winter months), but his banker has refused to give him a loan to buy a herd of gilts, self feeders waterers, portable shelters, and protein supplement for a year The banker feels the risk too great because (1) the young man has little experience, having grown up on a farm where no livestock was raised, (2) he is already in debt with machinery, and (3) hog raising doesn't look especially profitable at this time It is apparent this young farmer has the following essential parts of a livestock enterprise *labor, home raised feed* and a *minor share* of other capital items (rented land on which to set the buildings, and probably a wagon and tractor) He does not have *management ability*, or *capital* for hogs, protein supplement, buildings and equipment

The above situation is not unusual Many feed companies, packers, or others enter into numerous operations of this type on a contractual basis to provide management ability, feed, and some of the other needed capital They naturally expect a profit or return on their "inputs," as does the farmer Apparent is the fact that *neither* party *has* to enter into a contract agreement until each is satisfied that it is fair to him

As would be expected, the party who contributes least to or risks less

in the livestock operation, probably makes fewer *decisions*. This, of course, depends on the terms of the agreement, but usually the party which supplies most of the capital items makes the decisions on what to feed, when and where to sell, etc.

Many similar situations might be cited, with turkeys, broilers, laying hens, hogs, cattle, and lambs. Space doesn't permit detailed discussion of each species or variations which exist, but there are some generalities which should be mentioned.

Contract growing and feeding has been practiced where:

1. *Labor is cheap*. This is true in some southern states where there is little industry and people are not necessarily mobile—preferring to stay in their home areas even with low income.
2. *Capital is lacking*. Most young farmers lack capital. So do many others who want to specialize and expand.
3. *The operator wants to avoid risk*. This might be a young, married farmer who cannot afford risk, or perhaps one in semi-retirement who doesn't want to worry.
4. *Management skill and ability is lacking*. Raising livestock is a demanding business. Those new in the field—and some of the old ones—need and appreciate help in decision-making and management problems.

Those companies who have entered contract agreements have done so for many reasons, such as:

1. *Help sell feed*. Most feed company contracts dictate that their brand of feed be used exclusively for the life of the contract.
2. *Produce a uniform supply of product*. Meat packers, poultry processors, and egg distributors want to avoid seasonal peaks and valleys in receipts. They can operate more efficiently at a uniform rate. So contracts involving these groups closely control times of production and marketing.
3. *Produce a uniformly high quality product*. This may be accomplished by specifying certain breeding stock, breeding programs, and marketing weights.
4. *Make money on sidelines*, such as sale or lease of breeding stock, sale of disinfectants, equipment and buildings; or charging the producer interest rates higher than that paid for the capital.

The items mentioned above are not exclusive to contract operations. Other points might also be added.

Vertical integration is not new in business. It has been part of the automobile industry in the United States from almost the beginning. It is an accepted part of such other segments of the *food* industry as raising and processing canned and frozen fruits, vegetables, and pop corn. It is a noticeable episode in the drama of ever-changing agriculture and industry in a democratic economy.

11

FEEDING FOR REPRODUCTION

The heritability of prolificness is low This means that differences among animals in prolificness, on farms and ranches, are not caused nearly as much by differences in inheritance of the animals as by differences in environment—nutrition, presence or absence of disease, management, possible mechanical injury, etc (see Chapter 15)

Reproductive diseases (diseases and infections of the reproductive tracts in cows, ewes, and gilts as well as in bulls, rams, and boars) which inhibit or prevent reproduction can usually be diagnosed by a competent veterinarian Some may be treated and cured, others may be relatively incurable, so the animals are sold for slaughter Because these are problems for a specialist, they are not discussed in this text

Good management by the farmer or rancher will help prevent mechanical injury A hog raiser makes sure that gilts or sows near to farrowing do not have to crawl over a high door sill to get feed, water, or shelter They and bred ewes are kept separate from cattle during pregnancy Rough concrete floors around feeders and waterers assure good "footing," reducing injury by falls, which could cause embryonic death and abortion

Temperature and season influence fertility Extremely high temperatures decrease sperm production, motility, and vigor in rams, bulls, and boars This may be caused by high environmental temperatures in late summer or might result from infection or sickness In either case, the partial or complete infertility is usually temporary

There is some seasonal effect on ewes It is commonly believed that most ewes do not "come in heat" or accept the ram readily until the first cool nights of the fall This is true in many cases, but it has been learned in recent years that fertility of the ram earlier in the summer may be a greater inhibiting factor than fertility or receptivity of the ewe Again, breed differences exist Dorset ewes or crossbred ewes with Dorset ancestry are more likely than ewes of other breeds to come in heat and conceive, if bred during the late spring and summer

Nutrition is a major influence on prolificness, affecting both the potential sire and dam Sperm production health, and livability are influenced by

previous and present nutritional adequacy. Ova production, conception rate, and embryonic survival are also subject to nutritional influences. Health of the offspring at birth, and subsequent livability during the nursing periods, can be affected.

11.1 Critical Nutrients

Energy sources—carbohydrates and fats—are sometimes critical, not because they are inadequate but rather because they have been too plentiful and the ewe, heifer, or gilt is too fat. The same thing may be true for bulls, rams, or boars (see Section 11.2).

Certainly energy is needed for sperm and accessory fluid formation in males, and ova production in females. In fact, flushing (Section 11.3) is sometimes practiced, increasing the energy in the diet several weeks before breeding to encourage maximum ovulation and conception rate.

Protein is a critical nutrient, because it may be inadequate in some rations. This is especially true in arid range country where breeding stock may receive only dry grass or mature hay, both rather low in protein.

Sperm, ova, and the embryonic tissue which results at conception and develops in the uterus are composed primarily of protein. Epithelial cells which line the male and female reproductive tracts are protein in nature.

Viscous fluids, containing certain amino acids, carry the sperm; collectively the fluid and sperm are called semen. These fluids provide temporary nourishment to the sperm, insuring longer life. Fluids in the female reproductive tract also contain amino acids. They help reproduction by lubricating the tract and promoting eventual union of sperm and ova.

Hormones which control reproduction in both sexes of farm animals are composed of amino acids. These hormones regulate initiation of sperm formation, ova production and ovulation, and also help maintain pregnancy.

Vitamin A is critical because it also plays a role in epithelial health and integrity and because, like protein, it may be scarce if breeding animals receive only mature grasses and hays, or grains low in carotene, the precursor of vitamin A. These epithelial tissues which line the reproductive tracts of both sexes may, in vitamin A deficiency, become dry and hard, inhibiting fluid production and movement of sperm and ova, and preventing efficient implantation of zygotes.

Phosphorus may be considered a critical nutrient in reproduction because of the soil deficiency in many grazing areas where cow herds and sheep flocks are kept.

All nutrients essential for mature animals are needed by developing embryos because the same general functions are being performed. Except in certain areas or situations, other specific nutrients are not considered critical because they are normally adequate in typical rations.

11 2 Growth and Development of Breeding Stock

Farm animals that are extremely fat tend to be less prolific Though potential fatness may be inherited, the realization of this potential—getting the animals too fat—is caused by too heavy feeding Gilts, ewes, or heifers that carry too much finish may release fewer ova during the reproductive cycle and if conception occurs, fewer of the embryos may survive during pregnancy The reasons for decreased fertility are not completely clear

Because extreme fatness may impair reproductive efficiency, many breeders do not exhibit their breeding animals in major livestock shows after they reach breeding age In the past, competition and judging criteria have *encouraged* showing beef heifers and ewes, as well as bulls and rams, in a rather fat condition, apparently to prove the animals *had*, and therefore could *transmit* to their offspring the ability to fatten Actually, breeding stock is selected on farms and ranches *early* in life while yet growing, so such shows represent a somewhat artificial situation And it is foolish and embarrassing to show a supposedly top quality *breeding* animal in the show ring then find the cow or ewe will *not reproduce*

Oklahoma research[1] shows that feeding young heifers relatively low energy levels—just enough to maintain weight during the first winter as calves—does not materially reduce skeletal size at breeding time, or subsequent calf crop percentage Heifers fed at higher levels, in some cases gaining 150 or more pounds during the winter, conceived a bit more readily, but had more difficulty in calving Heifers raised at the extremely high levels gave less milk during lactation, perhaps due to fat deposition in udder secretory tissue during growth (see also Section 7 6)

[1] L. S Pope *et al* *Oklahoma Agr Exp Sta Misc Pub 55 57* and *64*

Figure 11 1 A herd of "working cows with their calves in a high mountain valley These are top quality cows with good production records "It doesn t pay to put fat on something you can t sell"! (*National Livestock Producer*)

More complete studies at Cornell University on dairy heifers have yielded considerable information on long time reproduction efficiency Study Table 11-1 carefully, including footnotes

Table 11-1. Influence of Energy Intake from Birth to First Calving on Reproduction Efficiency of Dairy Heifers*

Feeding level	Low	Medium	High
Measurements at puberty			
Number of animals	23	23	23
Av age, mos	20 50	11 30	9 30
Av weight, lbs	634 00	583 00	631.00
Av heart girth, in.	59 90	57 70	58.70
Av withers height, in.	46 90	44 90	45.60
First service			
Number of animals	33	34	34
Per cent conceiving at first service	79 00	68 00	58 00
Services for first conception	1 55	1 41	1 48
Performance to 1960[1]			
Number lost due to sterility	0	3	6
Services per conception[2]	1 61	1 85	1 82
Av weight of male calves[3], lbs	98 00	96 00	103 00
Av weight of female calves[4], lbs	90 00	93 00	94 00

*J T Reid *J Dairy Sci* 43 103, 1960 and private communication
[1]Some but not all cows had completed eight pregnancies
[2]Figures do not include animals eventually diagnosed as sterile
[3]Twins and premature calves not included

Puberty (evidence of first heat) was delayed considerably among heifers fed from birth at the low energy level, it was more a function of size than age

All heifers were allowed to mate at 18 months of age The percentage conceiving at first service was higher for those on a low energy ration, perhaps because they were older Average number of services for first conception was higher for the low energy group *only* because a *few* heifers required numerous services Such indicates that optimum level of energy may vary among animals Similar research at several institutions has shown heifers fed relatively high levels of energy from birth usually require more services per conception

Results of the study to 1960 indicate more efficient net reproduction among heifers fed from birth to first calf at a relatively low energy level Fewer cows were lost because of sterility, number of services per conception was less (even after removing sterile cows from data) and weights of calves were similar

The previous illustration simply indicates that breeding stock being developed need to be fed only for adequate growth, not for fattening Rela-

tively low levels of energy intake may delay physical and sexual maturity without lowering, and perhaps *raising*, net reproductive efficiency.

The "low" level of energy in the Cornell study was described as "65 per cent of standard nutrient allowances" (see Tables 7-1 and 7-2). Since there is much genetic variation among animals, as well as considerable environmental variation—quality of feed, management, stress conditions—among farms or ranches where heifers are raised, specific energy levels used in the studies presented should *not* be interpreted as recommendations for all farms and ranches. Continued research may, in time, provide bases for developing such recommendations, for specific herds and environmental situations.

The trend toward leaner hogs to provide leaner retail pork cuts has caused selection of leaner breeding stock and prolificness in this species has generally improved.

11.3 Flushing

A common practice among sheep raisers is to increase the grain allowance about a pound per day for ewes about two weeks before breeding, to promote ovulation and increase the number of multiple births. This is commonly known as "flushing" and is often, though not always, beneficial. When benefit does occur, it is apparently due to the increased energy consumption. As would be expected, prolificness is more often improved when thin ewes are "flushed" than when ewes in fat condition are fed additional grain.

Flushing might also be accomplished by turning the ewes onto an especially lush, growing pasture, where the forage is highly palatable and highly digestible.

Because a large percentage of ewes are maintained primarily on grass, most are in a rather thin condition before the breeding season begins. This probably accounts for the popularity and relative effectiveness of this practice in sheep flocks. Also, twinning is common in sheep, *if* breeding, nutrition, and management are satisfactory. The sharp increase in nutritional state is often the factor, apparently, which determines that twins shall be conceived, developed, and born rather than a single.

In cattle, however, twinning is not common. Though breeding heifers receiving a higher grain allowance prior to breeding may conceive earlier in the season (Table 11-4), calving percentage generally does not increase. Apparently other factors, besides nutrition, have a greater influence in limiting prolificness in cattle.

Flushing has not been popular in swine herds until recent years. With increased selection of lean breeding stock, and sometimes limited feeding of potential breeding animals before they reach breeding age, evidence indicates flushing of gilts and sows may be worthwhile.[2]

[2] B. N. Day, *Missouri Agr. Exp. Sta. Bull. 751*, 1960; Zimmerman, D. R. *et al.*, *J. Animal Science*, 16: 1099.

11.4 Pasture and Conception Rate

Three years of research at the Ohio Agricultural Experiment Station has demonstrated that certain legumes, such as ladino clover or birdsfoot trefoil, may delay conception in ewes (Table 11-2) and decrease the percentage that do conceive.

Table 11-2. Effect of Pasture on Conception Rate in Ewes*

	Bluegrass	Ladino clover	Birdsfoot trefoil
Time of first estrus (days after Aug. 31)	24.3	33.5	28.1
Time of conception (days after Aug. 31)	35.2	56.9	55.0
Number of services per pregnancy	1.5	2.1	2.3
Conceived first service, per cent	66.0	41.0	31.0
Per cent of ewes lambing	93.2	84.0	87.3
Lambing percentage[1]	125.3	115.7	114.5
Per cent lambs surviving to weaning	87.8	81.0	87.5

*Paul H. Engle *et al.*, *J. Animal Sci.* 16:703, 1957, and private communication.
[1] Based on ewes bred.

The lamb crop, as a percentage of total ewes bred, was markedly lowered. Also, because the delay in conception among many of the ewes on legume pasture meant the lambs were born over a long span of time, they lacked uniformity. Many were born too late to reach the choice grade in early summer when prices are highest.

Many of the ewes on ladino clover or birdsfoot trefoil did not conceive until *after a killing frost* had occurred, stopping the growth of the pasture. Perhaps estrogens present in the legumes inhibited ovulation and conception. Research has shown that low levels of stilbestrol (a synthetic estrogen) fed to calves, lambs, and gilts has decreased the number and size of developing ova. It is known that lush, growing legumes are high in estrogens and that estrogen content goes down when the plant dies, such as after a killing frost.

The above research supports observations of sheep raisers in the central United States that, though ewes gained well on good legume pasture, conception was often irregular and delayed. Research in New Zealand and Australia has shown delayed or inhibited conception among ewes grazing subterranean clover, considered an excellent pasture legume.

Influences of legume pasture on conception in cattle and hogs have not been demonstrated. It is reasonable, however, that estrogen activity in such feeds may exert some effect.

11.5 Pregnancy

Though a relatively high level of feeding just prior to breeding is important in all farm animals to insure production and release of many ova,

continued high level feeding after conception may *decrease* embryonic survival

Nutritive requirements for early fetal development in the sow, ewe, or cow are primarily protein and mineral During early pregnancy the embryos increase little in size, so energy needs are not high Tissue produced is primarily skeletal or is composed mainly of protein During the latter part of pregnancy, however, embryos grow considerably and energy requirements increase markedly Enough energy must also be supplied to allow the prospective mother to prepare for milk production after lambing, calving, or farrowing

Research at the Iowa Experiment Station (Table 11-3) and at other experiment stations has demonstrated the value of restricting feed intake early in pregnancy, using the feed saved for additional energy *later* in pregnancy

Table 11 3 Effect of Feeding Regime During Pregnancy on Swine Reproduction*

Corn silage per day, lbs	Even feeding 12 0		Low-high feeding 12 0	
20% concentrate mix per day, lbs	Gilts	Sows	Gilts	Sows
First two thirds of pregnancy	3 20	2 95	2 75	2 50
Last one third of pregnancy	3 20	2 95	4 55	3 75
Number of litters	59		53	
Litter weight, lbs	30 50		33 75	
Number of pigs farrowed	10 79		12 26	
Pig birth weight, lbs	2 83		2 76	
Number of live pigs farrowed	10 27		11 64	
Number of live pigs at age four days	6 89		9 65	

*C W Johnson *et al* *J Animal Sci* 16 600 1957

In the above case, all gilts and sows were handled similarly before breeding All received 12 pounds corn silage per day from breeding to the 110th day of gestation Concentrate feeding was arranged so that a gilt or sow received the same *total* concentrate during gestation, regardless of the feeding regime

Greater numbers of pigs farrowed per litter on the low-high system is the result of improved embryonic survival Pigs in the larger litters were naturally slightly smaller, so the survival rate to four days of age was not quite as good But an advantage of almost one pig per litter from sows on the low high group was maintained at four days of age

Level of feeding beef cows during pregnancy has received considerable attention Grass or harvested forage is the major energy source, but is

Figure 11-2. Silage is a good feed for pregnant sows and gilts because it is bulky and restricts energy intake. The same could be accomplished by restricted hand feeding or self-feeding a very bulky dry ration. (Iowa State University)

often supplemented with oilmeal (for protein) or grain (for energy). This supplemental feeding is relatively expensive.

Results of a long time Oklahoma study which began with weaned heifer calves in 1948 is presented in Table 11-4. Because of the relatively moderate climate, animals could graze year round and were given supplemental feed only during the winter, from November to April, when grass was drier, less palatable, and lower in protein and digestible energy.

Table 11-4. Influence of Level of Wintering (during pregnancy) on Reproduction Efficiency in Beef Cows*

	Low	Medium	High
Supplemental feed per day:			
Cottonseed meal, lbs.	1.00	2.50	2.50
Oats, lbs.	–	–	3.00
Number of heifers started in 1948	15	15	15
Av. weight Oct. 29, 1948, lbs.	473.00	471.00	476.00
Cows remaining, Nov. 1959	14	10	6
Av. weight Oct. 27, 1959, lbs.	1,066.00	1,149.00	1,099.00
Per cent calf crop, weaned[1]	92.30	89.20	88.60
Av. calving date	March 14	March 8	March 8
Av. calf birth weight, lbs.	77.30	76.90	78.50
Av. calf weaning weight, lbs.	479.00	479.00	468.00
Cow cost per cwt. calf weaned	$7.13	$9.66	$13.30

*Don Pinney *et al.*, *Oklahoma Agr. Exp. Sta. Misc. Pub.* 57, 1960, 60.
[1]Based on total number of cows bred to calve each year. Heifers calved first at two years of age.

Figure 11-3. Milk is nature's "most nearly perfect food" and when consumed in the above manner it doesn't require homogenization, pasteurization, mixing, or sterilizing of equipment. (Iowa State University)

Low level cows lost more weight during the winter but gained it back during the summer. Nutrient storage during the summer months was apparently great enough to provide nutrients for fetal development during the winter, even among heifers wintered at the low level. Also, heifers on the low level of supplemental feeding evidently consumed more forage during the winter than cows on the medium or high level.

In a companion study, where heifers calved first at *three* years of age, average calf crop percentage was reduced even more on the medium and high levels of winter feeding.

11.6 Nutrition and the Newborn

Colostrum, produced and secreted from the mammary gland the first three or four days after calving, lambing, or farrowing, is valuable. Colostrum is very high in protein, vitamin A, and minerals, and also contains large quantities of antibodies which help newborn animals resist disease and infection (see Sec. 30.4). Newborn animals have little antibody material in their blood at birth, so without the benefits of colostrum are very subject to disease.

Many dairy farmers routinely milk out all colostrum not used by calves, and freeze it for later use should a need arise. It may be valuable for a later calf, should its mother die or develop udder infection, and can also be used for orphan lambs and pigs.

Energy requirements for dams in all species of farm animals increase markedly at the beginning of lactation (Tables 6-6, 7-1, and 7-2). More

energy, and also more protein, minerals, and vitamins are needed for milk production than for development of the embryos in the uterus.

Health and livability of new-born animals can be greatly influenced by the feeding of the dam during gestation. Iodine deficiency in the gestation ration of sheep and vitamin A deficiency in the gestation ration of cattle were previously mentioned (Section 3.1). Animals that are small and weak at birth because of inadequate feeding during gestation have less chance of survival and often grow slower.

11.7 Feed Additives and Reproduction

Many feed additives such as antibiotics and stilbestrol have caused marked increases in growth. This may mean that certain animals will be heavier when they reach sexual maturity. Gilts, when fed rations containing certain antibiotics, may reach 200 pounds two to three weeks early, though sexual maturity has not been speeded up similarly. With heifers, however, most research indicates that weight at breeding time is not materially influenced by the use of antibiotics. The calves may grow faster early in life, when the antibiotics help resist certain low level infections, but any difference in size is essentially eliminated by breeding time.

Much research has shown that antibiotics in sow rations during gestation have little influence on litter size, birth weight, or livability. Very slight improvements have been noted in some cases but the differences have not been considered significant. It is apparent that continuous feeding of antibiotics to successive generations has no long-time effect on reproduction efficiency.

Since stilbestrol and other synthetic or natural "sex" hormones have been widely used in livestock feeding, many questions have arisen as to their possible effect on reproduction. Discussion of this topic here is *restricted* to the normal use of these materials at low levels in feeding programs and does not include possible use to control or treat reproduction cycles and phenomena.

When low levels of stilbestrol are included in rations for sexually immature calves, lambs, or gilts, growth of ova follicles on the ovaries is apparently inhibited. Ovaries of slaughtered animals fed stilbestrol have carried fewer follicles and those follicles present were much smaller. Therefore, immature females, intended for breeding, should not be fed stilbestrol-containing rations. Since about 60 per cent of the stilbestrol included in cattle rations appears in the feces, immature gilts intended for the breeding herd should not be used to follow stilbestrol-fed cattle in the feed lot.

Though these low levels of stilbestrol apparently inhibit ovulation, there is apparently no harmful effect after the animal has already conceived. Research at a number of experiment stations has indicated stilbestrol *feed-*

ing has no detrimental effect on embryonic survival Massive injections, however are routinely used to cause abortion of feed lot heifers

Other natural and synthetic hormones used in feeding—progesterone, estradiol testosterone, and others—are known to have noticeable effects on size and structure of certain reproductive organs, but drastic interference with reproduction has not been demonstrated when recommended levels are used

11 8 Feeds and Toxic Substances

Rye is often attacked by a flack fungus, ergot In Montana experiments, when sows were fed grain with one per cent ergot during pregnancy, many of the pigs were so weak that they died soon after birth and the sows showed almost complete lack of udder development The exact cause of this harmful effect of ergot is not yet known

When moldy corn is fed to gilts their vulva often appears pink and somewhat swollen as if they were in heat The condition is not accompanied by other signs of heat and disappears when the moldy corn is removed from the ration

Other influences of feeding and management on reproduction in farm animals are currently being studied The fund of knowledge in this area is expanding rapidly The cost of maintaining breeding herds and flocks provides much incentive for improving efficiency of reproduction

12

SHELTER AND FACILITIES FOR LIVESTOCK

Adequate knowledge of nutritional needs or desirable breeding programs are not the factors which limit livestock production on farms and ranches today We do need to increase our comprehension and mastery of these areas, and producers can make greater application of what is known, but the general area of management—shelter, equipment, and disease control—is currently the bottleneck in many cases (Figure 12-1).

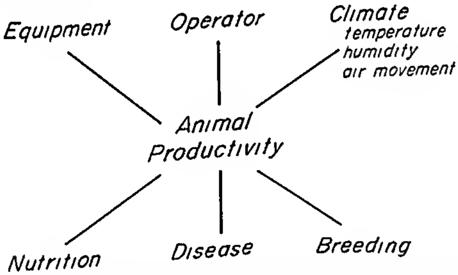


Figure 12 1 Some of the factors that influence animal productivity on farms and ranches Though knowledge in some fields would fill volumes application of the knowledge is made almost solely through the rancher or farm operator Knowledge in many fields often included under the term management is short and may be a bottleneck to production

We need to know the optimum climate—temperature, humidity, and air movement—for most efficient production, and the degree of impairment that results above or below the optimum Only then can we calculate the *relative profitability* of providing shade, fully insulated buildings, artificial heat, artificial cooling, fans, ventilators, dehumidifiers, sprinklers, etc

Animals vary in their reactivity to climatic stresses These variations are economically important, especially in areas of the country where climatic

extremes are typical Brahman cattle and other members of the Zebu group, for example are more tolerant of extremely high temperature and humidity than members of the English breeds Other differences will be discussed in a later section (Diseases and their control are not within the range of this text)

12 1 Temperature

Extremes in temperature are one of the most economically important stresses in livestock production High or low temperatures may inhibit feed consumption lower gains and feed efficiency (Table 12-1), decrease prolificness increase susceptibility to disease and infection, and indirectly or directly cause death of farm animals

Table 12 1 Predicted Effect of Air Temperature and Live Weight on Average Daily Gain in Swine*

Weight lbs	Degrees Fahrenheit of air							
	40	50	60	70	80	90	100	110
100	—	1 37	1 58	2 00	1 97	1 40	0 39	-1 32
150	1 27	1 47	1 75	2 16	1 82	1 14	0 19	-2 60
200	1 19	1 57	1 91	2 22	1 67	0 88	-0 77	—
250	1 10	1 67	2 08	2 14	1 51	0 62	-1 36	—
300	1 02	1 77	2 24	2 06	1 36	0 36	-1 95	—
350	0 94	1 87	2 41	1 98	1 21	0 10	-2 53	—

*Hubert Heitman Jr *et al* *J Animal Sci* 17 62 1958 The data were statistically tabulated from 24 different experiments involving pigs weighing 60 to 450 pounds

The optimum temperature for heavier hogs is lower than for lighter hogs as would be expected but the heavier hogs are more affected by temperature extremes

There is an approximate optimum temperature range for every animal depending of course upon factors such as size condition and ration The lower end of this temperature range is often referred to as the *critical temperature* and may be technically defined as the air temperature below which oxidations in the body must be increased to keep the animal warm Critical temperature for swine of various ages and weights is usually between 52° and 68° F Cattle which have winter coats and are being fed a maintenance ration have a critical temperature somewhat below 60° Beef cattle on full feed or dairy cattle in high production and consuming large volumes of feed have a much lower critical temperature Heat produced by utilization of the large quantities of feed is ample to keep the cattle warm at very low environmental temperatures

The upper limit of the optimum temperature range is more difficult to define and varies greatly among species

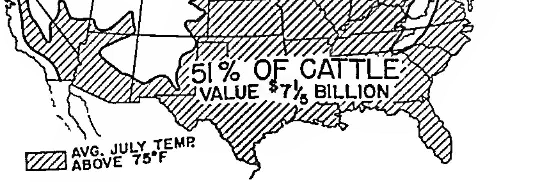
Understanding the severity of temperature effects, and also the factors which maximize or minimize these effects, requires review of several simple principles: (1) Evaporation is a cooling process, regardless of season; (2) low humidity speeds evaporation, high humidity inhibits it; (3) air movement speeds evaporation; (4) heat can be transmitted by radiation, convection, conduction, and other routes; (5) heat can be reflected off surfaces somewhat in proportion to the lightness or gloss of the surface. Most of the techniques used to combat temperature influences on livestock production employ one or more of these principles.

Discussion of the climatic stresses is divided into consideration of summer weather (Part A) and winter weather (Part B). Part C includes other aspects of facilities for livestock.

A. Summer Weather

In many sections of the United States the summer months provide more severely limiting effects on livestock performance than do the winter months. Over 50 per cent of the cattle in this country are raised in areas where the average summer temperature is above 75° F. (Figure 12-2). A majority of the hogs are now grown in the upper Midwest where winter weather is a major problem and summer heat not so drastic. But shifts in grain production to southern areas (Section 1.6) may mean more hogs will be grown there, and interest in keeping hogs cool will increase. There has been some increase, too, in the number of dairy cattle and sheep in the Southeast.

Figure 12-2. The 75° F. isotherm for average July temperature in the United States and approximate proportion and value of cattle in areas north and south of the isotherm. (Ittner, N. R., *et al.*, *California Agr. Exp Sta. Bull. 761*, 1958)



Animal productivity is markedly lower in most of the hotter regions of the earth Though a major reason for the lower production is probably the *direct* effect of hot climates on the animals, there are also other considerations The high degree of *parasitism* which occurs in most warm, humid areas may induce lowered production The *low protein* and *high fiber* content of deceptively lush looking forage in these areas may be partly responsible And, the cultural patterns of many tropical areas have not developed a high degree of technical *skill* in livestock raising

Most farm animals cannot dissipate excess body heat as easily and rapidly as humans Pigs do not perspire much and often have a heavy layer of fat, sheep have wool which provides insulation A typical cow, though she "perspires" some, has a maximum evaporative cooling rate about one eighth of a human, per unit of surface area A lactating cow has difficulty dissipating the heat she produces when the temperature is above 75° F[1]

Animals apparently have some ability to adapt to hotter weather Dairy cattle,[2] for example, may reduce hair thickness by shedding, may increase reflectivity by slight changes in coat color and by increasing skin secretions, and may reduce thyroid secretion to slow body metabolism and heat production

12 2 Shade

Shade is the simplest, and a relatively inexpensive, tool for combatting heat Shade trees scattered in the pasture or on the range are valuable Artificial shades can offer the same protection

Did you ever watch cattle lie in the shade? Especially if the weather is extremely hot, they pick shade on top of a hill where a breeze blows They lie on the north side and away from the tree, so radiant heat they emit will not reflect back from the lower branches

Properly designed shades will reduce radiation heat on cattle, hogs, and sheep up to 50 per cent Research indicates shades should be 10 to 12 feet high If possible they should be on top of a hill and be open on all sides If the long dimension of the shade is east west more radiation is prevented, but if the long dimension is north south sun may cover the entire area part of each day, improving sanitation If the roof slopes it should be high on the north side

A four to six inch layer of hay provided the coolest shade in California tests, where galvanized iron, aluminum, and boards (spaced two inches apart) were compared (Figure 12-3) Hay, held in place by wire above and below, has an insulating effect Heat from the sun does not penetrate

[1] H H Kibler and Samuel Brody *Missouri Agr Exp Sta Res Bull 574* 1954

[2] J E. Johnston *et al* *Southern Coop Series Bull 63* Louisiana Agr Exp Sta 1959

through to radiate onto the cattle, and little radiant heat from the cattle reflects back on the underside of the shade. Also, hot air under the shade can rise up through the loose bay.

If the metal or wood shade roofs are used, the top should be white or shiny to reflect all beat possible, and the underside should be dull and dark to avoid reflecting animal beat it receives. Shade roofs should be solid, without space between boards, for maximum benefit.

Sixty square feet of shade per animal is apparently adequate for cattle. Hogs and sheep need 20 to 30 square feet each.

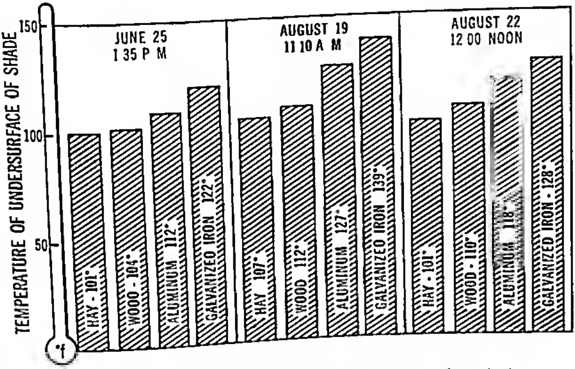


Figure 12-3. How roofing material influenced temperature of various shade structures. (Ittner, N. R., *et al.*, *California Agr. Exp. Sta Bull. 761*, 1958)

12.3 Air Movement

Air movement promotes evaporation, making cooling by perspiration more effective, and it helps remove heat dissipated by animals in the form of radiation, conduction, and convection. It also helps cool parts of the surroundings—fences, barn walls and roofs, earth, bunks, etc.,—which, in turn, helps keep the animals cooler.

Where heat is a problem, it is worthwhile to use wire or cable fences, which offer less resistance to air movement. Orientation of feed lots and corrals to take advantage of natural air movement is important.

Large fans for cattle confined to pens with wooden fences or to stanchion barns may be profitable (Table 12-2).

Table 12 2 Effect of Coolıng Pen Fed Cattle by Fan ın Extreme Southern Calıfornıa*

	1955 (July 6-Sept 14) Control	Fan	1956 (June 27 Sept 5) Control	Fan
Number of cattle	7	7	7	7
Initial weight lbs	669 00	669 00	657 00	645 00
Av daily gain lbs	1 29	2 32	1 87	2 40
Av daily feed lbs	17 18	21 41	18 36	19 18
Feed per lb gain lbs	13 30	9 24	9 82	7 98
Mean temperature	90 3° F		88 3° F	
Mean relative humidity percent	46 0		36 0	

*R N Ittner *et al* *California Agr Exp Sta Bull 761* 1958

Note that the benefit from the fan, ın terms of feed consumptıon, gaıns and feed efficıency, was much greater ın 1955 when the mean temperature and relatıve humıdıty were both hıgher Durıng the 1955 test, average aır velocıty ın the control pen was 0 63 MPH, ın the fan equıpped pen ıt was 3 7 MPH

Mıssourı tests have demonstrated that wınds of five to ten mıles per hour, provıded by fans, wıll help maıntaın mılk productıon ın daıry cows when temperature exceeds 80 degrees

12 4 Coolıng wıth Water

Sprınklers sanıtary wallows and commercıal or homemade evaporatıve water coolers have paıd bıg dıvıdends ın many cases Water pumped from deep underground ıs already cool, so the maın cost ıs pumpıng Evaporatıve coolers can operate cheaply, where natural wınd provıdes the evaporatıon

In Texas experıments[3] a concrete hog wallow, or foggıng or sprınkler system has consıstently ıncreased gaıns ten per cent when the average temperature ıs 85° F or above Table 12 3 summarızes three years research ın southern Georgıa wıth pıgs hoggıng down corn (1954 and 1955) and beıng fed graın and supplement on natıve grass pasture (1956)

[3] Hale Fred *et al* *Texas Agr Exp Sta Bull 866* 1957

Table 12 3 The Value of a Water Sprınkler for Hogs ın Georgıa*

	1954 (June 25 Aug 13) Control	Sprinkler	1955 (June 28 Aug 23) Control	Sprinkler	1958 (May 15 - July 17) Control	Sprinkler
Number of pigs	22	23	14	17	48	48
Av daily gain lbs	1 31	1 63	1 25	1 54	1 76	1 86
Mean max temp	96°		91°		89°	
Mean min temp	72°		72°		67°	

*W C McCormick *et al* *Georgia Agr Exp Sta Mimeo Series N S 27* 1956

Both groups had ample shade every year. The sprinkler, in each case, was simply a garden hose with an ordinary nozzle adjusted to permit a continuous fine spray. As was true in previous research reported, additional cooling was more beneficial in the hottest seasons, though an advantage of 0.10 pounds per day was observed in 1956, when the mean maximum temperature was only 89° F.

Studies in the northern part of the United States have also demonstrated that swine show the effects of heat when temperatures reach 80° F. The rate of breathing increases and, at 90° F. or above, respiration rate may increase to 150 to 200 per minute and body temperature goes up. These effects are probably more severe in the eastern Corn Belt where humidity is higher.

Research at Purdue has demonstrated the value of a wallow or spray in addition to shade (Table 12-4).

Table 12-4. Wallows or Water Spray for Hogs in the Corn Belt*

Item	1956 (June 18 - August 20)			1957 (June 18 - July 19)		
	Control	Wallow	Spray	Control	Wallow	Spray
Number of pigs	12	12	12	12	12	12
Av. initial weight, lbs.	85.00	85.00	85.00	132.00	132.00	132.00
Av. daily gain, lbs.	1.89	2.04	2.09	1.58	1.50	1.75
Av. daily feed, lbs.	6.80	7.20	7.52	6.48	8.34	7.13
Feed per lb. gain	3.60	3.52	3.59	4.16	4.22	4.08

*F. N. Andrew *et al.*, *Purdue University Agr. Exp. Sta. Mimeo. A.H. 186*, 1956, *and 212*, 1957.

Though the pigs having access to a wallow in 1956 made almost as rapid gains as those having the spray, those with the wallow made the *poorest* gains in 1957. In 1957 all pigs were affected by influenza and those in the wallow were affected most severely. This illustrated the sanitation and disease control problem inherent with a wallow.

The size of fall litters was greatly increased in Oklahoma[4] research by cooling gilts and sows during pregnancy. The cooling system consisted of a mist sprayer under an open shade. Sows that had only shade farrowed an average of 7.71 pigs per litter, while those protected from heat by the shade *and* water mist farrowed 10.06 pigs per litter.

Water cooling is naturally more effective in arid climates where evaporation is quicker. In humid areas, sprinklers can actually *increase* humidity and *lower* evaporation. With cattle in humid areas, a fine spray that wets only the outer hair coats serves as an insulator, preventing heat dissipation. In such cases, water cooling can be effective only if *cold* water is used and

[4] J. A. Whatley, Jr. *et al.*, *Oklahoma Agr. Exp. Sta. Misc. Pub. 48*, 1957.

Table 12.2 Effect of Cooling Pen Fed Cattle by Fan in Extreme Southern California*

	1955 (July 6-Sept 14) Control	Fan	1956 (June 27-Sept 5) Control	Fan
Number of cattle	7	7	7	7
Initial weight, lbs	669.00	669.00	657.00	645.00
Av. daily gain, lbs	1.29	2.32	1.87	2.40
Av. daily feed, lbs	17.18	21.41	18.36	19.18
Feed per lb. gain, lbs	13.30	9.24	9.82	7.98
Mean temperature	90.3° F		88.3° F	
Mean relative humidity, percent	46.0		36.0	

*R. N. Ittner *et al.* *California Agr. Exp. Sta. Bull.* 761, 1958

Note that the benefit from the fan, in terms of feed consumption, gains, and feed efficiency, was much greater in 1955 when the mean temperature and relative humidity were both higher. During the 1955 test, average air velocity in the control pen was 0.63 MPH, in the fan-equipped pen it was 3.7 MPH.

Missouri tests have demonstrated that winds of five to ten miles per hour, provided by fans, will help maintain milk production in dairy cows when temperature exceeds 80 degrees.

12.4 Cooling with Water

Sprinklers, sanitary wallows, and commercial or homemade evaporative water coolers have paid big dividends in many cases. Water pumped from deep underground is already cool, so the main cost is pumping. Evaporative coolers can operate cheaply, where natural wind provides the evaporation.

In Texas experiments[3] a concrete hog wallow, or fogging or sprinkler system, has consistently increased gains ten per cent when the average temperature is 85° F. or above. Table 12-3 summarizes three years research in southern Georgia with pigs hogging down corn (1954 and 1955) and being fed grain and supplement on native grass pasture (1956).

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Av. daily gain, lbs	1.31	1.63	1.25	1.54	1.76	1.86
Mean max. temp.	96°		91°		89°	
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[4] J. A. Whatley, Jr. *et al.*, *Oklahoma Agr. Exp. Sta. Misc. Pub. 48*, 1957.

if the animals are soaked to the skin Wetting the outer wool of sheep would also be a hindrance

Water may be most effectively used to cool beef or dairy cattle by spraying a mist on hay or burlap shade, erected to the windward side of the feed lot or loafing area Such a system works well for hogs, especially where there is no concrete floor and excess water can drip outside the pen Wherever sprays are used they are most efficient if the mist is so fine that it almost evaporates before it reaches the floor or ground

When dairy cows in Louisiana[5] were sprinkled with water during the summer months when maximum daily temperature averaged about 90° F, milk production increased slightly among Holsteins but there was practically no increase among Jerseys All cows were given shade

Commercially constructed evaporative coolers, designed for homes or offices, can also be used Since these are relatively compact and enclosed, a powered fan is needed to force air movement needed to give substantial evaporation and cooling

Remember that evaporation of moisture from grass likewise gives a cooling effect To illustrate, stand at the leeward end of a dry, plowed field on a hot summer day, then move to the leeward end of a clover or alfalfa field Breeze blowing off the forage will be considerably cooler than from the plowed field So why not put your brood sows under some shade on a slight knoll just north of the clover field (assuming traditionally southern summer breezes)?

12.5 Refrigerated Cooling

Cooling with water is less effective in humid areas and where there is less air movement. It offers some sanitation problems, and water supply is sometimes critical Also, because humidity and air movement fluctuate, it is hard to maintain a relatively *uniform* cooled atmosphere and *refrigerated* cooling is sometimes necessary

An increasing number of swine raisers have insulated buildings for year-round farrowing and confinement rearing, including forced ventilation and a complete duct system for heating The next step, toward refrigerated air conditioning seems practical in some cases The main cost is the refrigerator unit Complete insulation of the building makes the cooling effective and efficient With lowered humidity, temperature doesn't need to be lowered as far Profitability naturally depends on cost versus increased productivity and feed saving (Figure 12-4)

Profitability of refrigerated cooling for cattle would be less likely, because of the larger size and greater heat production of the animal Value of keeping rams in cooled chambers during a summer breeding season is discussed in Section 13 2

[5] L. L. Rusoff *et al* *Louisiana Agr Exp Sta Bull 497*, 1955

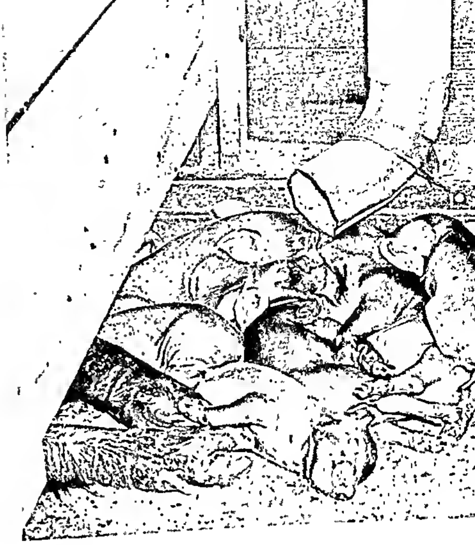


Figure 12-4. It is cheaper to pipe refrigerated air directly onto sows and little pigs in hot weather. Note how comfortable the pigs are. The same ducts can be used for hot air in the winter. (*Successful Farming* Magazine)

12.6 Water Supply and Temperature

Ample water has long been proven essential for economical livestock production. Livestock will drink three to eight times as much water as they will consume feed. In hot weather they need more.

Cattle on the range[6] tend to do most of their drinking in the forenoon and the late afternoon and evening, as long as air temperature is below 80° F. As temperature increases, cattle drink oftener, and at 90° F. they tend to drink at least every two hours. This means that wells in the ranches of the hot Southwest need to be fairly close. There is naturally a practical limit, but many ranchers arrange wells so a cow is never over a mile from water even though grazing areas are vast.

South Dakota research has shown that over 300 feet between feed and water will reduce pig gains in dry lot. This may be important with lambs and cattle on feed, though probably less so because of the volume of water "stored" in the rumen.

Cooling the drinking water for feed lot cattle may increase animal comfort and performance. In four southern California tests daily gains were 0.19 to 0.50 pounds higher when water was 65° F. rather than 90° F.

Mechanical cooling of water may often be uneconomical, but several

[6] C. B. Roubicek *et al.*, *Arizona Agr. Exp. Sta. Report 154*, 1957.

other techniques will help Water from wells is colder than from ponds or creeks Shade over a tank will keep water two to three degrees cooler A shallow tank means fresher water (and cooler if from a well) and water in such a tank stays cooler because of surface evaporation

12.7 Ration

The proper ration for hot weather is extremely important in livestock production Regardless of species, *high fiber* diets should be avoided Such feeds produce a high 'heat increment," which means a large amount of extra body heat develops in the process of digesting and utilizing such feeds This extra heat must be dissipated, a difficult task in hot weather In general, summer rations should contain considerable *concentrates* and any roughage used should be *top quality* and highly digestible

Poultry raisers sometimes use a 'top' feed to help maintain feed consumption in extremely hot weather This is especially important where lowered consumption may cause a prolonged production slump The top feed usually contains extremely high levels of trace minerals and B vitamins Certain B vitamins actually stimulate appetite This high potency feed may be sprinkled on top of the regular ration periodically in hot weather or fed in limited quantities after the feeders have been empty for an hour or so Such a practice might have value in swine feeding

B Winter Weather

The effects of winter weather have long been noted by livestock raisers because of the effect the weather has on the human In fact, it might be that some farm buildings have been designed to protect the farmer more than to protect livestock

The shelter needs of hogs are similar to those of humans In general they are about the same size, they consume the same types of diets, and their body metabolism including temperature control system, is similar

Cattle and sheep, however, are markedly different and have less need for shelter, especially when mature Sheep have a heavy insulating coat of wool and therefore are naturally adapted to cold temperatures Cattle are much *larger* animals, therefore have less surface area per unit weight This means *less* body heat, in relation to that produced, is lost And since both these species are ruminants, they eat roughages which have a *high heat increment producing* more heat inside their bodies relative to size

12 8 Minimum Shelter

Minimum shelter needs are much higher for young animals in winter months Because they are smaller and less symmetrical, they have more

Figure 12-5. Mature cattle, such as these cows near Walden, Colorado, need little shelter during the winter. (American Hereford Assn)

surface area per unit weight, and relatively more heat is lost by evaporation, radiation, convection, and other routes. Anything which might increase this loss, such as *wet bedding* or *drafts*, is especially harmful.

The temperature-regulating mechanism is also apparently not fully developed in young animals. This includes ability to increase metabolism to provide more body heat, to constrict surface capillaries to prevent heat loss, etc. This is especially critical with baby pigs because of their small size.

Mature animals need less shelter, especially if they are on a high feed intake where considerable heat is produced as a natural by-product of digestion and metabolism. Ewe flocks on the open ranges of Wyoming and Montana seldom need more shelter than the leeward side of a hill, unless blizzards are especially wet and prolonged. The same is true for cow herds or yearling stocker cattle. Yearlings and two-year-old cattle on feed in the northern Midwest, if kept dry, usually need only a windbreak or open shed.

Ventilation is mighty important in shelter for cattle and lambs on feed since humidity builds up in closed sheds or barns quickly. Then moisture condenses on walls, the bedding gets wet, and the cattle or lambs develop colds or other respiratory trouble. If confined to such shelter, their hair or wool may get damp and they chill when they go out to eat in a cold wind.

Calves naturally need more shelter than older cattle, but even here a shed closed on three sides is ample and ventilation must be adequate.

Effects of cold weather on feed lot performance are more noticeable with hogs than with cattle and sheep (Table 12-1).

12 9 Providing Heat

The economy of providing artificial heat for cattle or lambs on feed or for breeding herds and flocks has not been generally demonstrated Though extra heat for weaned pigs on feed may be worthwhile, the greatest value of artificial heat is at lambing and farrowing time and for several days or weeks thereafter Extra heat for newborn calves is seldom needed if housing is adequate

A number of heating systems are used, some of which are mentioned here

Heat lamps are popular for newborn pigs and lambs They not only provide direct heat, but also help the newborn animal dry off and prevent chilling If properly placed in farrowing pens or stalls, they help *attract* pigs away from where the sow might lie on them Most brooders are simply a combination of a heat lamp and a hover which helps hold the heat down near the floor where it does the most good A thermostatically controlled heat pad, on which pigs or lambs might lie to keep warm, is also used

Many swine housing units are now constructed with heating facilities imbedded in the floor These might be electric cables or pipes for steam or hot water (the pipe system can also be used for air conditioning) Where farrowing stalls are permanent, such floor heating might be located where the baby pigs should eat, drink, and lie, to the side of where the sow lies In growing houses, for weaned pigs, floor heating is usually concentrated on the higher floor section, away from the alleyway Feeders and waterers are usually placed adjacent to the alleyway and pigs are encouraged to nest on the higher floor level Hovers extending out from the wall are helpful for young pigs, keeping the heat near the floor and helping to prevent drafts in large buildings

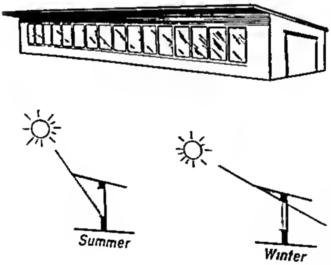


Figure 12-6 A typical "solar" house showing large space devoted to windows on the south side and the effectiveness of the angle of the sun in heating

Hot air heat, from central furnaces, space heaters, and other heating equipment, can be adapted to certain livestock operations. Merits of each depend on such factors as the job to be done, the building, equipment, cost of installation, and power cost.

Some swine and poultry houses are built to take advantage of solar heat. Numerous thermopane windows on the south side allow much radiant heat from the sun to enter (Figure 12-6). This can be very effective and practical if the building is well insulated, though such windows are expensive. Roof overhang is calculated so the sun doesn't shine in the windows during the hotter months, but does provide needed warmth during seasons when the sun is lower and more heat is needed. Roof overhang can also be adjustable.

12.10 Heating Water

Heating water, above the temperature needed to keep it from freezing, has not proven worthwhile in most cases for cattle, hogs, or sheep. Holding water at 10 or 20 degrees above freezing temperature, in various experiments, has not consistently improved feed consumption, gains, or feed efficiency.

Water is most easily and cheaply kept from freezing if waterers are inside or well-sheltered, a small amount of water is exposed to the cold, and the water is kept fresh and moving. A system has been devised and used in which water is pumped continually through waterers and back into an underground pipe and a reservoir. Unless temperatures are extremely cold and waterers are not protected, the earth keeps the circulating water warm enough to prevent freezing.

12.11 Ventilation

Air movement, primarily to hold down humidity, is essential for confined livestock *regardless of temperature*. Most ventilating systems in use are inadequate.

The quantity of air that needs to be moved naturally depends on number and weight of animals confined, temperature inside and outside, and humidity of the outside air. Ventilation should be designed according to the *maximum* needs anticipated.

Ventilation needs can be held down by using less water in cleaning, providing steep floor slopes and floor drains so much urine and water escapes as liquid, and using minimum bedding.

Because ventilation is so critical, some old ramshackle buildings are actually better for cattle, sheep, and hogs because they are well *ventilated*. Unless animals are very young, they can withstand a lot of cold as long as they are *dry* and protected from strong winds, sleet, and snow.

C Other Environmental Stresses

Mud! Regardless of season mud is a stress both to animals and to the feeder or farmer The Corn Belt feeders and those in the East and Southeast suffer more from mud than do feeders in the arid Southwest

Cattle tests at Purdue University have illustrated the value of concrete feeding floors in wet seasons In a wet year cattle on concrete ate about 0 7 pounds more feed and gained over a half pound more per day, materially improving feed efficiency There was little benefit in a dry year Similar benefits might be expected for lambs

The value of concrete floors for hogs might be much greater than for cattle or sheep because of the greater sanitation problems and also from the standpoint of feed wastage Pigs certainly have difficulty getting around in the mud because they are built close to the ground Monetary advantage of concrete feeding floors cannot be stated for all conditions, but most feeders in temperate or humid areas figure that *it pays*

13

ANIMAL REPRODUCTION

Reproduction in farm livestock and poultry, as in other mammals and birds, is accomplished by union of the male sex cell, the *sperm* with the female sex cell, the *ovum,* in the female reproductive tract and by gradual development in the reproductive tract of the individual or egg thus formed. This chapter will describe the sperm, and where and how it is produced, transported, and united with the ovum. It will similarly tell about the ovum, and will describe the cycles of events that are peculiar to the female reproductive tract.

13.1 Male Reproductive Organs

The reproductive organs of the male are similar among most species. Those of a bull are diagrammed in Figure 13-1.

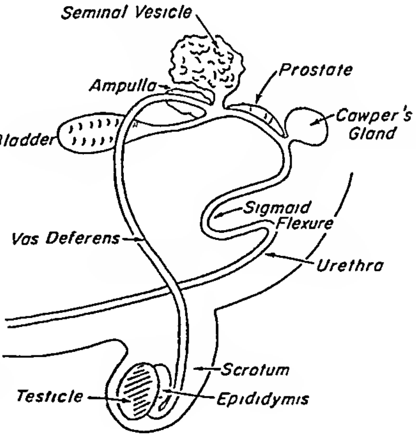


Figure 13-1. The reproductive tract of a bull with the individual organs or parts identified. Tracts of other males are similar.

The two testicles, which produce both sperm and male sex hormone, are suspended outside the abdominal cavity in the scrotum The scrotum apparently helps control the temperature of the testicles Extremely high temperatures interfere with sperm production, so on hot days the scrotum descends, moving away from the body heat and creating more surface area for heat dissipation

The epididymis is a storage reservoir for sperm between services, since sperm production is relatively continuous after sexual maturity A tube (vas deferens) from each testicle leads into the body cavity where the two unite and join the urethra near the bladder The urethra, therefore, carries both semen (during mating) and urine

Note the various accessory organs located near the junction of the vas deferens and the urethra A primary function of these organs is to produce fluid which carries, nourishes, and perhaps activates, the sperm

13 2 Sperm Production

After sexual maturity of the male, sperm production is continuous under most conditions There is much individual variation in age at sexual maturity and initiation of sperm production, but averages are given in Table 13-1

Table 13 1 Average Days of Age When Sperm Are First Produced*

Boar	147	Ram	147
Bull	224	Chicken	84-140
Goat	110		

*From A V Nalbandov, *Reproductive Physiology Comparative Reproductive Physiology of Domestic Animals Laboratory Animals and Man* W H Freeman and Company, San Francisco 1958

In chickens sperm production normally continues at the same general rate throughout life, but in most mammals production gradually declines in advanced ages Because there is much individual and breed variation in age at sexual maturity and also in duration of sperm formation, these traits might be selected for and gradually changed in a herd or flock

Sperm cells result from the transformation and division of special sperm "mother cells' in each testicle The final division which produces new sperm is a special kind of cell division called *meiosis*, which reduces the chromosome number by half Meiosis is explained in detail in Chapter 14

A new sperm cell consisting of a head, a middle piece, and a tail (Figure 13 2) is not immediately capable of fertilization It must first undergo a series of maturation processes in the testicle as well as in the epididymis where the sperm are stored

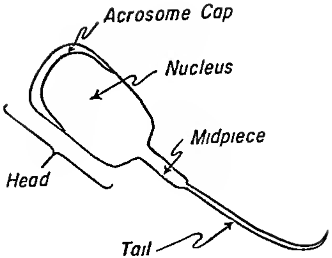


Figure 13-2. Diagrammatic sketch of a bull sperm magnified about 2400 times

Sperm are minutely small, occupying as little as 1/20,000 the volume of the ovum, even though they are equivalent in hereditary significance [1] Unlike ova, which are produced in small numbers in the female, sperm are produced continuously and in large numbers A typical ejaculate of bull semen may contain over five billion sperm, sufficient to inseminate at least 500 cows Numbers of sperm per ejaculate are also high for other species (Table 13-2)

Table 13 2 Approximate Sperm Production in Several Species*

Species	Average volume, cc	Millions of sperm per cc	Potential number of matings per ejaculate
Bull	4	300-2000	100-600
Ram	1	800-4000	40-100
Stallion	50-100	30-800	8-12
Boar	200-250	25-1000	4-8
Cock	0 2-2 0	0 5-60	6-10

*E J Perry, *The Artificial Insemination of Farm Animals* Rutgers University Press, New Brunswick N J , 1960

Many environmental factors, as well as heredity, influence rate of sperm formation Environmental effects are usually only temporary Extreme underfeeding, especially after animals have been well fed, will decrease the formation This is particularly significant when bulls or rams are put back with the herd or flock after being fattened for show

Vitamin A and protein seem to be the critical nutrients involved in sperm formation in most areas of the country Lack of these nutrients is most common in dry seasons

[1] M W H Bishop and C R Austin "Mammalian Spermatozoa," *Endeavour*, XVI 137-150

Extremely high temperatures will decrease sperm formation and also cause a higher proportion of sperm which are incapable of fertilization. Low conception rate among ewes bred during late summer is common, and many sheep raisers now keep their rams in a cellar or air conditioned stall and let them out with the ewes only at night. High body temperatures that result from sickness or infection will also impair sperm production.

13.3 Accessory Fluids

Sperm are carried in a viscous mixture of fluids, the entire mass being called *semen*. These fluids are produced primarily by the accessory organs along the male reproductive tract (Figure 13.1), though a small portion may come from the testicles or the epididymis.

In general the fluids are added to the sperm only at ejaculation. In some species it has been demonstrated that fluids from one certain organ 'flush' the tract ahead of other fluids which might carry sperm. All functions of the fluids may not be completely known and may not be the same in all species. The main functions, however, are apparently to serve as a medium for sperm movement, to activate the previously nonmotile sperm cells, and to supply metabolizable nutrients and other essentials. The fluids contain sodium chloride, potassium chloride, nitrogen, citric acid, sugar, and several vitamins, which may be utilized by the sperm cells for energy and metabolic processes, as well as certain enzymes. Certain accessory fluids also serve as lubricants during the mating process.

13.4 Female Reproductive Organs

The various parts of the female reproductive tract are diagrammatically illustrated in Figure 13.3. The ovaries of the female correspond to the testicles of the male: they are the site of the formation of the sex cell, the ovum. Released ova move through tubes, called oviducts, to the uterus.

The ovaries are located near the kidneys in the body cavity, suspended in loose connective tissue as are other internal organs. The uterus, where embryos develop during pregnancy, lies immediately under the terminal end of the large intestine in large animals. The cervix, an orifice which is opened or closed during certain stages of the female reproductive cycle, connects the uterus to the vagina. Sperm are deposited in the vagina during natural service and may be deposited there or in the uterus by artificial insemination.

Two horns of the uterus are evident in Figure 13-3. The forward end of each horn leads into a small convoluted tube, which extends to the vicinity of the corresponding ovary. The proximity of the ends of these tubes to the ovaries varies among species, but in all species they insure passage of released ova toward the uterus. Cases have been known of a female becom

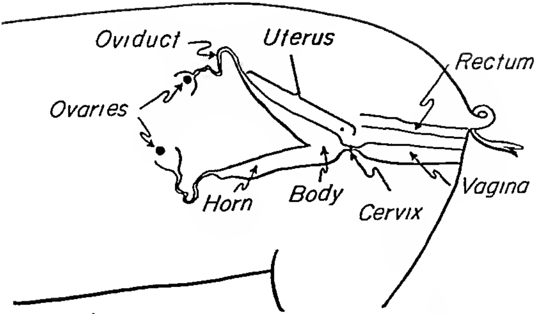


Figure 13-3. The female reproductive tract of a gilt The horns of the uterus are diagrammatically tilted 90° and extended, in the drawing, to be visible. Uterine horns in sheep and cattle are not so distinctly separate. The photo shows a gilt tract, alongside a meter stick. Note the ovaries, with developing follicles, at the end of each horn (Photo, Iowa State University)

ing pregnant even when one ovary had been *removed* and the *opposite* tube was *tied off* to restrict ova passage to the uterus. Body movements apparently insure that released ova reach the uterus. In poultry, only the left ovary is functional.

13.5 The Female Reproductive Cycle

Whereas sperm production in males is continuous after sexual maturity and males are prone to mate at almost any time, the release of the female sex cells in mammals occurs in cyclic patterns, in relatively small numbers, and ewes, gilts, and cows will accept a male only at certain times. The reproductive organs of the female are geared to a regular, hormone-controlled cycle, interrupted only by pregnancy or by season (in certain species). This cycle is called the *estrous cycle*.

The estrous cycle is initiated by certain hormones at the time known as "sexual maturity" (puberty). Completion of the estrous cycle is marked

by *"heat"* or *estrus*, the time when the female will accept the male. The estrous cycle might be defined, then, as the cycle of events from one heat period to the next. It includes the gradual development and release of the ova, other physiological changes in the female tract which prepare it for pregnancy, and heat or estrus. Length of the estrous cycle and also of heat in various animals is given in Table 13-3.

Table 13-3. Length of Estrous Cycle, Duration of Heat, and Time of Ovulation*

Species	Days in cycle	Duration of heat	Time of ovulation
Cow	21	13-17 hours	12-15 hours after end of heat
Sow	21	2-3 days	18-40 hours after start of heat
Ewe	16	30-36 hours	12-18 hours after start of heat
Goat	19	39 hours	9-19 hours after start of heat

*From A. V. Nalbandov, *Reproductive Physiology: Comparative Reproductive Physiology of Domestic Animals, Laboratory Animals, and Man*, W. H. Freemand and Company, San Francisco, 1958.

13.6 Formation and Release of Ova

Ova formation in the ovary corresponds to sperm production in the testicle. Ova result from the division of special cells in the ovary, with the chromosome number in the resulting ova cells being reduced by one half. Whereas sperm production in males occurs after sexual maturity, ova are produced earlier, even during embryonic development of the female. These ova remain latent until the female approaches puberty.

Hormones produced in the female, as it approaches maturity, cause enlargement of follicles, each of which contains a single ovum. In litter-bearing animals, such as gilts, several follicles develop simultaneously, perhaps some on both ovaries. In other species, such as cattle, only one follicle may fully develop. The mature follicle, distended by accumulated fluid, protrudes from the ovary surface like a water blister, near the end of the estrous cycle.

During or after heat (Table 13-3) the follicle or follicles gradually rupture, releasing the ovum from the follicle along with the fluids. This is called *ovulation*. The ovum or ova then pass down the oviducts leading toward the uterus.

13.7 Mating and Conception

Both the sperm and ovum are living cells, but each has a limited span of life. Sperm of mammals seldom live longer than 30 hours after entering the female reproductive tract (though sperm of poultry usually live longer, some surviving as long as 30 days). Ova probably survive longer, but

Figure 13-4. Identical twins result when an ovum divides after fertilization. They have, therefore, identical genotypes. (Iowa State University)

evidence indicates that embryos resulting from older ova are much more likely to die before implantation or during development. This means that in natural service matings must be made near the time of ovulation.

In natural service ejaculated semen, containing millions of sperm cells, is deposited in the vagina. The sperm move rapidly through the cervix and uterus, and up the oviducts, often in a matter of minutes. This movement of sperm is probably caused by uterine contractions stimulated by hormones.

Ova move down the oviduct much more slowly, often requiring several days.

Fertilization, or union of the sperm and ovum, invariably occurs in the oviduct. Though sperm reach the oviduct and vicinity of the ovum within minutes after mating, evidence indicates that the first sperm may not be the one which fertilizes the ovum. Research with rabbits indicates sperm may need to remain in the oviduct environment several hours before being capable of fertilization.

The exact, detailed process of sperm and ovum combination is not completely known. In some species the surface of the sperm head attaches itself to the ovum and secretes an enzyme which may allow the sperm to enter the ovum. The tail of the sperm, giving some motility, may also help the sperm penetrate the membranes around the ovum. Enzymes of the sperm apparently continue to play a role as the head, and then the tail, of the sperm penetrate the ovum and become engulfed in the ovum cytoplasm. Membranes surrounding the ovum then change to prevent entrance of other sperm.

Inside the fertilized egg, the nucleus of the sperm and the nucleus of the egg come into close contact nuclear membranes disappear, and the complete chromosome groups become evident Then begins the first cell division and growth of the zygote

The fertilized ovum, or zygote, if it survives continues to move slowly down the oviduct to the uterine horn where it attaches to the uterine wall The zygote may include several cells by this time, as the result of cell division At the implantation site, capillaries develop to nourish the developing embryo during pregnancy

The optimum time for mating, to achieve the highest conception rate, is influenced by the time of ovulation in relation to the heat period In cattle, more will conceive at first service if bred near the end of heat, since ovulation does not occur until 12 to 15 hours after heat The cow must be receptive to the bull, but the sperm should not be deposited longer than necessary before ovulation

In ewes and sows where ovulation occurs during, but near the end of heat, it is easier to synchronize mating with ovulation

13.8 Artificial Insemination

Artificial insemination is used for several reasons (1) to spread more widely the merits of a top quality sire, (2) to eliminate the cost and risk of maintaining a sire for a small herd or flock, and (3) to prevent spreading of certain reproductive diseases Artificial insemination is not new, it was reported used as early as 1322 in horses

Because a single ejaculate of semen contains many times the number of sperm needed to breed a female, the semen can be diluted and used in smaller portions Table 13-2 gives the number of females that might be inseminated per ejaculate of semen in several species Semen to be used for artificial insemination may be collected by use of a dummy, a teaser cow, or an electro-ejaculator The latter instrument causes ejaculation over a 15 to 20 minute period by means of electric impulse With a dummy or teaser cow semen is collected in an "artificial vagina," made of soft rubber and maintained at body temperature

The semen is checked for sperm concentration and motility, then diluted to the desired concentration If it is to be used fresh, it is usually maintained at exactly 40° F, or under carbon dioxide at room temperature For storage and later use, it is frozen slowly Freezing, like hibernation, slows metabolism Because the sperm are single, living cells with little environmental protection, they must be handled with care Special diluents which help keep the sperm alive are used Because a drastic temperature change can kill sperm, the temperature is lowered very slowly If bovine semen is held below −110° F, it can be stored successfully for several years

For use, the frozen semen is thawed slowly It is then deposited by

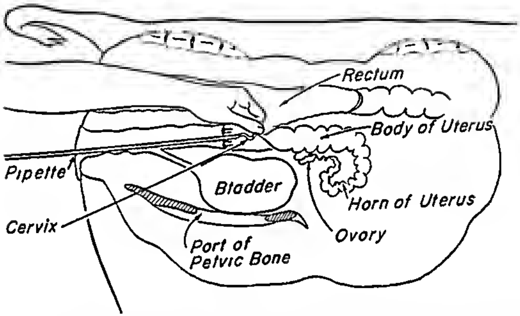


Figure 13-5. For inseminating cows, the left hand is inserted into the rectum to guide the pipette through the cervix. This is not possible with sows (Iowa State University)

means of a pipette or other instrument into the reproductive tract of the female (Figure 13-5). Usually the pipette is inserted through the cervix and the semen is deposited directly into the uterus. If any vitality of the sperm has been lost during storage, depositing the semen in the uterus may be of benefit.

13.9 Pregnancy

The period of time during which the fetus develops in the uterus is called pregnancy. After conception and implantation of the fertilized ovum to the wall of the uterus, the regular estrous cycle is interrupted for the duration of pregnancy. Approximate length of pregnancy (gestation period) is given in Table 13-4. It varies considerably among animals and is influenced by age, breed, and number of embryos developed.

Table 13-4 Length of Pregnancy in Farm Animals*

Cows	282 days
Sows	114 days
Ewes	150 days

Maintenance of pregnancy is dependent upon progesterone, a hormone produced by the *corpus luteum*, which develops from follical scar tissue *on the ovary* after ovulation Degeneration or removal of the corpus luteum invariably results in abortion

It was mentioned in Section 13 7 that age of the ovum at time of fertilization may influence maintenance of pregnancy, in that older ova are less likely to survive after fertilization Nutritional influences on maintenance of pregnancy and number of embryos surviving are discussed in Chapter 11 The many reproductive diseases which can terminate pregnancy by abortion or resorption, such as brucellosis and leptospirosis, are not discussed here

Though fertilized ova divide rapidly, embryos are still very small even after two thirds of pregnancy has elapsed Most of the tissue growth occurs during the last one third of pregnancy (Figure 13 6)

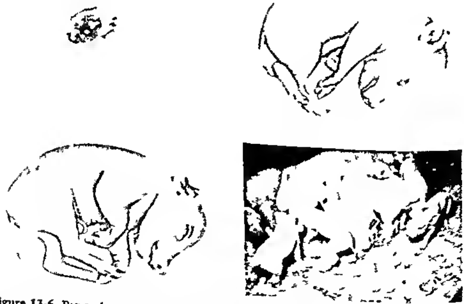


Figure 13-6 Pig embryos at certain stages of pregnancy and a litter soon after birth. Large amounts of nutrients are required for tissue growth in the last one third of the pregnancy period (Ralston Purina Company)

14

HOW INHERITANCE WORKS

How are characteristics inherited—passed from one generation to the next? The only physical link between generations is the pair of reproductive cells, the sperm from the sire and the ova from the dam, which unite at conception. The answer may lie, then, in these cells, what they contain, how they develop in the testicle of the sire or ovary of the dam, how the zygote divides after conception, and just how the contents of these cells exert their effects. These topics are all included in the discipline called genetics.

To gain an appreciation of genetics, and to have it answer a few questions effectively, you must first acquaint yourself with a few terms. A *gene* is the simplest unit of inheritance. Physically, a gene is apparently a chemical compound called a nucleic acid. Nucleic acids, ultramicroscopic and therefore invisible even through powerful microscopes, contain several units each of simple sugars, phosphate, and nitrogen-containing compounds. These units might be hooked together in a variety of patterns, so various genes differ in their chemical structure.

A *chromosome* carries many genes in a row, like peas in a pod. Apparently a chromosome is a long protein molecule, to which are chemically attached the various nucleic acids (genes). Each gene occupies a *specific* location on a *certain* chromosome. Chromosomes occur in pairs in most body cells. So, then, do genes. One member of each pair of chromosomes is inherited from the male parent while the other member of that pair is inherited from the female parent.

The number of chromosome pairs in cells of farm animals is given in Table 14-1. The total number of genes in cells or on certain chromosome pairs is not known.

Table 14-1. Chromosome Pairs in Farm Animals

Cattle	30	Pigs	19
Horses	33	Sheep	27
Goats	30	Chickens[1]	6
		Turkeys[1]	9

[1]Estimates based on recent research evidence.

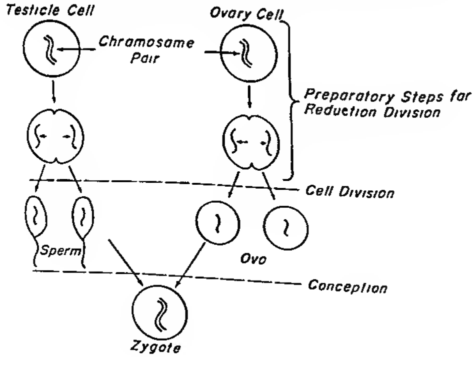
Though much genetic study is directed toward individual genes and how they work, most economically important traits of farm livestock are influenced or affected by *many* different genes Transmittal of single genes or a very small number of genes can be easily studied, and a few livestock examples are given in later sections But when many genes are involved, inheritance patterns are not so simple and different techniques are used for studying them These procedures, so important in farm animal inheritance, are discussed in Sections 14 5 through 14 7

14.1 Transmission of Genes

Every cell in the body, except sperm and ova, has a full set of chromosome pairs Each sperm and ovum carries one member of each chromosome pair This is accomplished by "reduction division" (meiosis) during the development of the sperm cell in the testicle, or the ovum in the ovary (Figure 14-1)

Note that in formation of the sperm cell in the testicle a normal cell divides *after* one member of each chromosome pair migrates to each end of the cell Two sperm are formed from one normal cell These sperm develop as described in Chapter 13 and in time are capable of combining

Figure 14-1 Sequence of events in reduction division to form sperm and ova, then combination at conception to form zygote This illustrates a single pair of chromosomes The same thing happens simultaneously to every pair of chromosomes



with an ovum produced by the ovary of the female. Cell division in the ovary of the female is similar. The ovum formed and shed from the ovary contains one member of each pair of chromosomes that was present in the original cell.

Reduction division differs from mitosis, which is normal cell division during tissue growth. In mitosis *everything* inside the cell, including *each member* of the chromosome pairs, divides so that the new cells formed contain *a full complement* of chromosome pairs, and the resulting new cells are *exactly* like the original cells.

It is emphasized that the sperm and the ovum each contain *one member* of each chromosome pair. When a sperm and ovum unite, then, the resulting fertilized cell (zygote) contains a full set of chromosome pairs. Chromosome Number 1 present in the sperm matches up with Chromosome Number 1 present in the ovum. The other chromosomes pair up similarly.

Since the genes are carried on chromosomes, things that happen to chromosomes also happen to genes. One member of each pair of genes migrates *as a part of* the chromosome to opposite ends of the cell. When the cell divides each new sperm or ovum carries *one* member of each gene pair. Then, at conception, when the members of the chromosomes match up, the genes automatically do likewise.

14.2 Examples of Simple Inheritance

All livestock traits, visible or measurable, are influenced by one or more gene pairs. In most cases the economically important traits are influenced by several gene pairs.

First let us study some characteristics which are influenced by just one pair of genes. The mechanism of inheritance is relatively simple. These examples will also illustrate to us why offspring may be *similar* or *dissimilar* from their parents in certain characteristics.

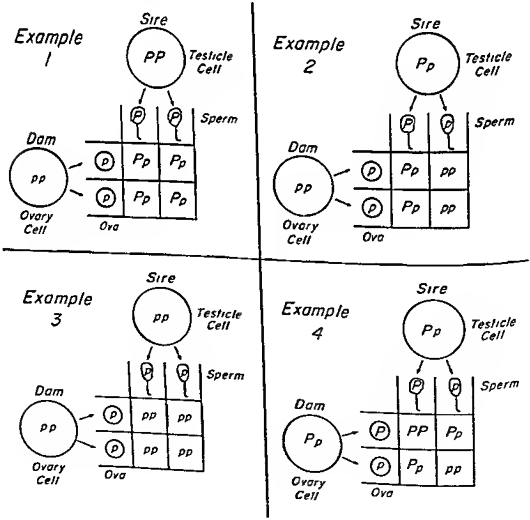
The first illustration is the polled characteristic in European breeds of beef cattle. *P* designates a gene for the polled characteristic; *p* designates a gene for horns. If the genotype (genetic make-up in the cell) is *PP*, the animal is polled. If the genotype is *pp*, the animal is horned. If the animal received a *p* from one parent and a *P* from the other parent, the genotype is *Pp* and the animal is polled. The polled gene (*P*) is dominant over the horned gene (*p*). Geneticists use capital letters to denote dominance and small letters to denote recessiveness.

In the preceding paragraph there were several new terms introduced. Perhaps these should be explained in more detail. *Genotype* refers to the genes and gene combinations on the chromosomes in the cells of the individual. The *phenotype* of an individual is the visible or obvious characteristic, such as the presence or absence of horns. In the above example if

the genotype is *pp* the phenotype is *horns* If the genotype is *PP*, the phenotype is *polled* The same phenotype would be observed with the genotype *Pp* We see, therefore, that the phenotype or visible characteristics of an animal do not always disclose the genotype

Illustrations in Figure 14-2 provide bases for discussing inheritance of the polled characteristic In Example 1 the sire has the genotype *PP* The dam, or cow, has the genotype *pp* After reduction division in the testicle, one *P* is present in each of the sperm that develops After reduction division in the ovary of the dam, one *p* is present in each ovum produced Regardless of which sperm unites with which ovum at conception, the resulting zygote will contain the *Pp* genotype and the offspring will be polled

Figure 14 2 Four different types of mating involving the gene for the polled trait Note the proportions of genotypes which occur in the offspring and also how an offspring may differ in genotype from either parent



In the second example, where the sire is also polled but has a different genotype, *Pp*, two kinds of sperm will be produced. Half will contain the *P* gene; the other half, *p*. All ova produced by the dam will contain the *p* gene. So if by chance a sperm containing the *P* gene unites with an ovum, the resulting zygote will have a *Pp* genotype and the calf will be polled. If, however, a *p*-containing sperm unites with the ovum a horned calf with the *pp* genotype will be born.

What determines which type of sperm will unite with a particular ovum? Only *chance*. In this case half of the sperm carry the *p* gene, half carry the *P* gene. So it is a 50:50 chance that either will unite with a particular ovum.

In the third example both the sire and dam are horned (genotype *pp*). Obviously any zygote formed will carry the *pp* genotype; these are the only genes that can be transmitted from the parents.

Both the sire and the dam are polled, in Example 4, but their genotype is *Pp*. Half of the sperm will carry *P* (for polledness) and half will carry *p* (for horns). The same will be true of the ova. Chances are 25 per cent that a calf born will have the *PP* genotype, 50 per cent that it will have a *Pp* genotype, and 25 per cent that it will carry a *pp* genotype. If a large number of such matings are made, 75 per cent of the calves will be polled; 25 per cent will be horned. Further recognize that two-thirds of the polled calves will carry a recessive gene *p* for horns. It is obviously impossible to look at a polled animal and tell whether or not it carries the recessive *p* gene. (Small horn-like scurs, more often seen on male calves in breeds or families that are generally polled, are apparently caused by a different set of genes.)

The above series of illustrations shows that much of inheritance involves the laws of chance.

Another characteristic apparently influenced by just one pair of genes is the color of Angus cattle. *B* represents black, and is dominant over *b*, which represents red. Most Angus cattle carry the *BB* genotype. A few carry the *Bb* genotype. These, of course, are not apparent since they are black. A few individuals carry the *bb* genotype and are red.

In recent years a Red Angus breed association has been organized. The red Angus apparently originated from matings of two black cattle where both carried the red recessive gene. It is apparent that Red Angus cattle will *breed true* for color when mated within the breed. Since they carry only the *b* gene for color, this is the only gene they can transmit to their offspring.

A third characteristic apparently influenced by only one pair of genes is the "snorter dwarf" characteristic in beef cattle (Figure 14-3). Dwarf calves often die at birth or soon after. Those which live grow slowly and inefficiently, and are an economic loss to the producer. *N* represents normal body size; *n* represents dwarf. Since *N* is dominant over *n*, it is difficult

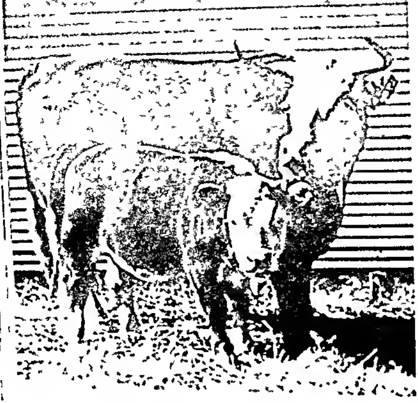


Figure 14-3. A dwarf calf with its normal-appearing dam The cow is apparently a "heterozygote" for the dwarf gene. (Iowa State University)

to pick out the normal-sized animals which carry the dwarf gene. Only when such animals produce a dwarf calf are they positively identified. Since *n* is recessive, both parents are then known to carry this gene.

In this situation, though *N* is dominant and *Nn* animals appear essentially normal, there are a *few* tell-tale signs that expose some dwarf gene *carriers*. Often the dwarf carrier bulls or cows have shorter front legs and a shorter, wider head Since the dwarf gene is so undesirable, present research is being directed toward *positively* detecting the individuals which appear normal but carry the dwarf gene.

The previous illustrations show why some offspring are like their parents in certain characteristics and some offspring are *not* like their parents. One can also understand why a pig or calf or lamb may resemble its dam in certain traits and the sire in certain other characteristics.

Not all cases of simple inheritance involve complete dominance and recessiveness There may be *partial* dominance, or two members of a gene pair may be equal in *power*, neither being dominant over the other. Color of shorthorn cattle is an example. *R* designates red, *W* designates white. An animal with an *RR* genotype is red, one with a *WW* genotype is white, and one with an *RW* genotype is usually roan or spotted.

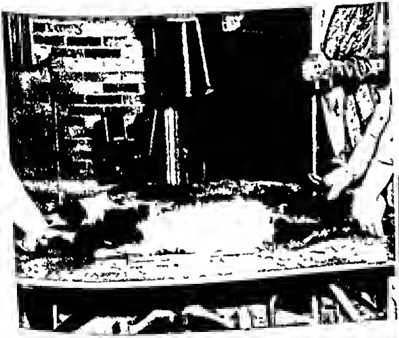
14.3 Genotype and Phenotype

The *genotype* of an animal is a listing of the specific genes carried on the chromosomes The *phenotype* is a summary of the *visible* or *measurable* characteristics. A black Angus bull may have the genotype *PPBBNN*, indicating he is polled, black, and normal in size. If this were true, the geno-

type and phenotype would correspond. Since *P*, *B*, and *N* are dominant, it is apparent the phenotype of an animal discloses some information about the genotype. *Any* Angus that is polled, black, and normal in size must carry at least one *P* gene, one *B* gene, and one *N* gene.

Breeders want to know as much as possible about the genotype of their breeding stock. They know a normal size bull carries one *N* gene, but what do they know about the second member of the pair? A bull calf born without horns is known to carry one *P* gene. How can you know what the other gene is? Or suppose a bull calf born with horns was dehorned early and there is no evidence that the horns were ever present. Obviously the phenotype, in this case, does not disclose the genotype.

One object of livestock research is to seek out phenotypic characteristics which serve as a better indicator of genotype. It has been learned, for example, that definite ridges or protrusions appear on the bodies of the lumbar vertebrae of dwarf cattle. These malformations can be detected by x-ray when the calves are a few days of age (Figure 14-4). Of special value in selection of breeding stock is that dwarf carriers (genotype *Nn*) usually show evidence of an intermediate malformation, so can be identified before being put into a breeding herd.



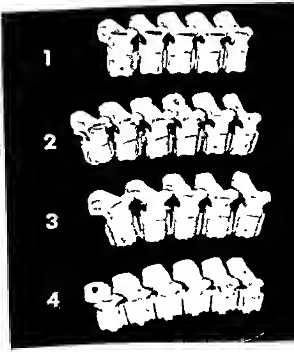


Figure 14-4. A suspected dwarf carrier on the x-ray table at left. The right photo shows cleaned lumbar sections from (1) normal, (2) and (3) carrier, and (4) dwarf calves. Note ridges on the ventral sides of 2, 3, and 4. Carriers do not all appear identical. (Iowa State University)

sure that the genes which inhabit each location are on the "positive" side That is, we want these genes to be the ones which will cause *faster* gains, *more efficient* feed utilization, *higher* quality carcasses, *higher* milk production, etc , rather than genes which might work in the opposite direction We almost forget the concept of dominance and recessiveness, though we recognize it does continue to play a role

Evidence indicates that in economically important characteristics, dominance works in our favor It is apparent that, more often than not, dominant genes are the good genes—at least in the characteristics of fast growth, efficiency, litter size, and a few other characteristics (Section 18 5).

14.6 Effective Improvement by Selection

Four rules for effective improvement of livestock by selection are listed below Following these rules closely allows progressive breeders to make relatively rapid progress It is assumed, of course, that selection is based on *economically important* traits The four rules are

1 *Have maximum genetic variation* This is further discussed in Section 14 7
2 *Spend selection efforts on traits largely influenced by heredity* This means the traits where phenotype is a good indicator of the genotype Chapter 15 is devoted to the different traits in this respect
3 *Observe or measure accurately* the traits carried by a prospective breeding animal (Chapter 16)
4 *Use the selected animal or animals* (carrying the traits you want) *most effectively* Effective programs are discussed in Chapter 17

14.7 Genetic Variation

Many livestock breeders and students of animal science believe that uniformity is desirable in a breeding herd or flock For effective and rapid improvement by selection, this *is not true*

Breeders naturally take much pride in a herd or flock that is uniformly *good* This is certainly justifiable But the emphasis should be on *merit* rather than on *uniformity per se*

Cattle and lamb feeders like to buy uniform groups of animals for feeding Packers are usually impressed by groups of slaughter hogs, lambs, or cattle that are uniform in size, conformation, and finish They often bid higher on such a group than on a group of the same average quality but with more variation Carcasses from a uniform group might all be sold to the same retailer, and there is less chance of there being an extremely low quality animal in the group

This preference for uniformity, justifiable in certain cases, is well imbedded in the livestock industry Prospective buyers of breeding stock are often noticeably impressed by extreme uniformity in the herd or flock in

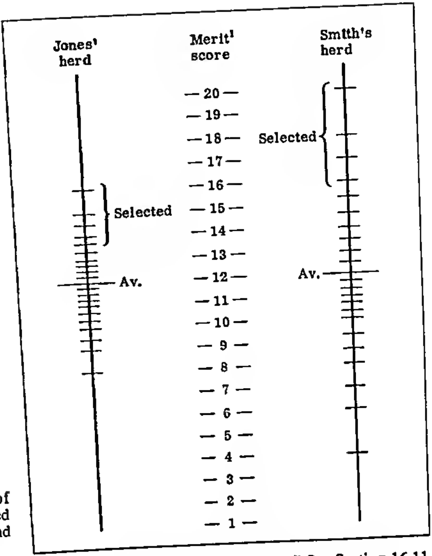


Figure 14-6. A "scale of merit," on which are plotted gilts belonging to Jones and Smith.

1 Might be called an "index." See Section 16.11.

which the breeding stock was raised. But a selected breeding animal—bull, ram, boar, or female—doesn't transmit "uniformity" or "variation" to their offspring. They transmit *genes.*

Also realize that a breeding herd doesn't exist just to be looked at and to take pride in. On most farms and ranches they exist *to be improved* and to serve as a source of progressively better breeding stock for commercial producers. And *little* improvement can be made *within* a herd or flock that is extremely uniform (Figure 14-6).

The groups of gilts owned by Jones and Smith, illustrated in Figure 14-6, average the *same* in total merit score, though Jones' gilts are much more uniform. Both breeders plan to keep the five best gilts in their herd for breeding and will sell the remainder for slaughter. Which breeder will make the most *improvement* in quality?

Smith will obviously make much *more* progress. First, the better gilts will be easier to identify because they are *much* better than the poor ones. Also, their phenotypic rank is *more apt* to be a true indicator of their genotypic rank or relative *breeding quality.* And the average of *selected* gilts is *much* higher in Smith's herd than in Jones'.

Smith can "reach" farther by selection, so his progress will be faster.

In many traits the phenotype doesn't disclose fully the genotype. Though a ewe lamb may carry genes favorable for rapid growth, heavy wool production, and high prolificness at maturity, *environment* will determine whether or not the genes are ever demonstrated. The lamb's mother may die soon after birth, leaving her without proper nourishment, and she grows slowly. She may not receive an adequate ration, but one low in protein, so wool growth is impaired. And after maturity, she might be mated to a sterile ram, so her genetic prolificness is not demonstrated.

Environment often greatly *masks* genotype, or hereditary potential. This topic is discussed in more detail in Chapter 15.

14.4 Inheritance of Sex

What determines the sex of a zygote? Again chance. Each normal body cell contains a pair of chromosomes called the sex chromosomes. Among mammals both members of this chromosome pair are similar in the female and are called *X*. Hence the female genotype for the sex characteristic is *XX*. One chromosome of the male is like that of the female and is called *X*; the other has a different content of sex genes and is designated *Y*. The male genotype, therefore, is *XY*.

Just how the *X* and *Y* chromosomes differ is not presently known. Geneticists generally agree, however, that such designations be made for the sex chromosomes.

In reduction division in the testicle, the *X* chromosome from the sperm mother cell becomes a part of one sperm, the *Y* chromosome inhabits the other. Half of the sperm carried in semen, therefore, carry the *X* chromosome, half carry *Y*. Ova shed in the female, however, carry only the *X* chromosome.

At conception there is a 50 per cent chance that an *X*-carrying sperm will unite with an ovum to produce a zygote with an *XX* genotype (a female). There is also a 50 per cent chance that a *Y*-carrying sperm will unite with an ovum and a male zygote (*XY*) will develop. Hence, we say that sex is determined by chance. Small variations from the 50 per cent proportion of males and females born are not unusual. These may be due to chance, to difference in survival or activity of sperm carrying different sex chromosomes, or difference in survival of embryos according to sex. There is no known scientific basis for the common belief that certain matings will produce a high percentage of one particular sex.

14.5 Most Traits Influenced by Several Gene Pairs

In livestock improvement, it becomes necessary to go on from relatively simple inheritance patterns and recognize quickly that *most* economically important traits, such as rate of gain, body type and conformation, milk

production, and carcass merit are influenced by *several* gene pairs It becomes very complicated to trace inheritance of a trait when two, three, or more pairs of genes are involved The number of possible gene combinations in individuals becomes tremendous.

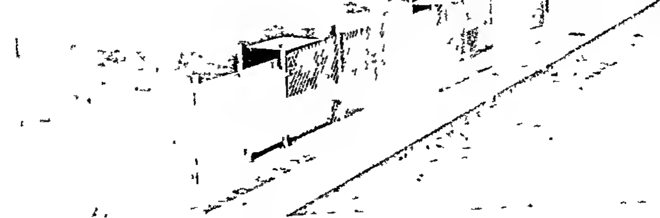
Improvement of livestock on farms and ranches by selection boils down to the task of selecting animals with *many good genes*. This is accomplished by putting all candidates for herd sire, or all potential replacement heifers, gilts, or ewes, in the *same or similar environment* and then selecting the one that performs best in terms of the characteristic being selected for—gain, finish, feed efficiency, wool production, etc. (Figure 14-5). The one that *performs the best* in a certain trait when the environment is held constant is probably the one with the *most good genes* for that trait.

This concept may not be as glamorous or as striking as our discussion on horns or dwarfism, but it is the whole foundation of practical livestock improvement Though the improvement possible under these situations is achieved slowly, ultimate possibilities for improvement are practically unlimited. It is the technique by which we improve herds and flocks in the livestock industry.

We know, for example, that milk production in livestock is influenced by at least ten pairs of genes. The percentage of butterfat in milk is influenced by at least ten pairs It is reasonable to assume based on genetic studies, that other economically important characteristics are influenced by relatively large numbers of gene pairs.

If we assume that each pair of genes occupies a particular location on the chromosome, then our goal in livestock selection is simply to make

Figure 14-5. Since swine testing stations provide a relatively uniform environment, genetic merit of hogs from different herds can be compared (Iowa State University)



15

HERITABILITY

Heritability may be defined as the *relative* importance of heredity in influencing certain livestock traits The only *other* influence, of course, is environment Heritability of traits may range from zero to 100 per cent Turn to Section 3 1 for a quick review of where in the life cycle of farm animals heredity and environment exert their effects

15 1 Heredity vs. Environmental Influences

Since the genotype (heredity) of an animal is established at conception, it can be said that the genetic *potential* of an animal is determined then If genes for prolificness, rapid gaining, efficient feed utilization, high carcass merit, and other desired traits are provided by the uniting sperm and ovum, the embryo which develops and is eventually born has a high genetic potential The degree to which the potential is reached during the animal's lifetime is determined by environment—ration, housing, climate, incidence of disease, management, etc If environment is excellent, the high potential may be approached or even reached The best rations, shelter, sanitation, and management will allow rapid gains, efficient feed utilization, efficient reproduction, and top carcass quality

If the genotype of an animal provides a low potential, however, it is apparent that even the *best* rations, shelter, sanitation, and management will not give top production Good environment will help, though, and will allow the animal to demonstrate the *limit* of its productive potential

Environment may influence some traits more than others, after the potential (genotype) has been established at conception The polled trait in beef cattle is established by heredity (genotype *PP*) Coat color is established by heredity An Angus with genotype *BB* is black, one with *bb* is red True breeding Duroc hogs transmit only the red hair coat Suffolk sheep transmit the distinctly black color markings on the head and shanks These traits are high in heritability, heredity is the major influence and environment exerts little effect

But how about prolificness? Think of all the environmental factors that can *encourage* or *limit* litter size in hogs, the per cent calf crop in a cow herd, or the incidence of twins in a sheep flock Fertility of the sire, time

during "heat" when bred, ration amount and quality, incidence of disease, possibility of mechanical injury, and other factors are all important Even though the genetic potential has been established, many different environmental factors can exert much influence on whether that potential is reached Heritability of such a trait is usually low

It is apparent that both heredity and environment influence all livestock traits, but in varying degrees Figure 15-1 illustrates one technique used to demonstrate effects of both heredity and environment on rate of gain in cattle

	Pen 1		Pen 2		Average	
	Animal	Daily gain	Animal	Daily gain		
Twins A & A′	A	1 20	A′	1 80	1 50	Hereditary difference = 0 20
Twins B & B′	B	1 40	B′	2 00	1 70	
Average		1 30		1 90	1 60	

Environmental difference - 60

Figure 15-1. The above illustrates that differences in livestock performance can be caused by both heredity (genes) and environment In this case the difference in environment had a greater influence on rate of gain than did the difference in heredity

Two sets of identical twin steers were used, one member of each set being fed in Pen 1 and the other member of each set in Pen 2 The two pens were in different locations, there was a contrast in shelter provided, and rations fed in the two pens were different Steers A and A′ were not related to steers B and B′

The difference of 0 6 pounds gain per day between the steers in Lot 1 and those in Lot 2 indicates a sizeable environmental influence It is not apparent which of the contrasting environmental influences exerted the largest effect—ration, location, or shelter

Averages in the right column indicate a *genetic* difference in gaining ability Since one member of each pair was subjected to the same environment, this difference of 0 2 pounds per day is apparently hereditary

In the above case environmental factors had more influence on rate of gain than did the differences in heredity This is not always true If the two pens had been adjacent, with similar rations and facilities, the difference caused by environmental factors would have been smaller

15 2 What Heritability Means

Heritability was previously defined as the relative importance of heredity in influencing certain livestock traits Heritability might be defined another way There are many differences among animals in *each* characteristic The

total *variation* that exists among animals in a certain trait is caused by heredity and environment. The *proportion* of the variation or differences caused by variations in heredity (ancestry or parentage) is the heritability.

If, for example, no caustic, cutters, saws, or other device were ever used for dehorning cattle and no broken horns occurred by accident, presence or absence of horns on cattle would be caused solely by differences in genotype. Heritability of this trait would be essentially 100 per cent. Actually, however, accidents and fights do occur, some farmers and ranchers dehorn while some do not, and there is variation in how good a job they do. Environmental variations do exist, so presence or absence of horns is not caused solely by heredity. Heritability of the trait is therefore somewhat less than 100 per cent.

Heritability means other things too. It means the *degree of relationship* between *genotype* and *phenotype* in a certain trait. For example, if heritability of leanness (muscling) in hogs is high, a boar's degree of leanness should disclose fairly closely his genotype for leanness. (Remember that most traits, such as leanness, are influenced by many genes and the individual genes aren't named or designated. But in this case it would be apparent whether or not the boar carried many genes which promoted leanness.)

Heritability means the degree of relationship between phenotype and *breeding value*. If heritability for leanness is high, a lean boar has "lean" genes, and these are the genes he will transmit to his offspring.

At Miles City, Montana, a few years ago a "Line 10" bull ranked top in rate of gain among seven bulls tested on a standard ration. A year and a half later steers sired by each bull were compared in a similar feeding test. The group of steers sired by the "Line 10" bull ranked first. In no case were the progeny (offspring) better or worse than their sires by more than one rank. This illustrates that rate of gain is heritable, influenced considerably by heredity.

15.3 The Trait is Heritable

The *trait* is heritable, *not* the animal. Though we must select or reject a potential breeding animal as a unit, we select because of the traits they carry. Heredity establishes the potential of all traits, but environment influences some much more than it influences others. Therefore, heritability of different traits varies *within* a species (Table 15.1).

Note that, regardless of species, those traits related to body or carcass structure and physical composition are more *highly* inherited than ranch or feed lot performance traits, especially traits observed or measured before weaning. This simply means that environmental factors on farms and ranches—ration, housing, disease control, management, etc.—can be a greater *benefit* or *detriment* to prolificness, preweaning growth rate, or livability before weaning than they can be to body composition.

It may be worthwhile to discuss the influences of environment on certain traits, starting first with those low in heritability.

Prolificness is generally low in heritability. Sows that were members of large litters don't necessarily produce large litters. A number of experiment stations have demonstrated that ewes born as singles are almost as

Table 15-1. Approximate Per Cent Heritability of Certain Livestock Traits*

	Dairy cattle	Hogs	Beef cattle	Sheep
Type and conformation				
Conformation score	25	30	25	15
Face covering				55
Skin folds				40
Amount of spotting (Holsteins)	95			
Number of functional nipples				20
Reproduction efficiency:				
Services per conception	5			
Reproduction interval	0		10	
Gestation length	30	20		
Number born		10		10
Birth weight	60	5	40	30
Production				
Mature weight	60			
Weight at weaning		10	20	30
Post-weaning pasture gains			30	
Post-weaning feed lot gains		25	45	
Feed efficiency		30	40	
Staple length				40
Milk produced	30			
Butterfat produced	25			
Per cent butterfat	50			
Health and soundness:				
Heat tolerance	20			
Mastitis resistance	25			
Cancer eye susceptibility			30	
Longevity	10			
Carcass traits				
Length		60		
Number of vertebrae		75		
Loin eye area		50	65	
Thickness of fat covering		50	40	
Belly thickness		50		
Per cent ham		50		
Per cent shoulder		55		
Per cent fat cuts		50		
Per cent lean cuts		60		
Tenderness		35	60	
Carcass grade			35	

*Adapted from W A Craft, *J. Animal Sci* 17 960, Maurice Shelton and O L Carpenter, *Texas Agr. Exp Sta Lamb Report 21*, 1957, E. J. Warwick, *J Animal Sci* 17 922, and National Research Council, *Handbook of Biological Data*, 1956.

likely to give birth to twins as ewes that were born as twins Since multiple births are rare in cattle, the interval between calvings is used as a measure of prolificness, and the heritability of this, too, is generally low Note that the heritability of services required per conception is low among dairy cattle Environmental factors, such as disease or injury, may be the main reasons cows don't settle at the first service

Many swine breeders consistently mark and save for breeding ooly gilts that are from large litters The value of this practice might be questioned The large litter demonstrates that the dam had a genetic potential for high prolificness and that environment was apparently favorable for realization of this potential Presumably, some of the genes for prolificness would be transmitted to the gilts in question But there is no guarantee that environment will be equally favorable for these gilts

Similarly, there is no guarantee that gilts of a small litter will inherit a *low* genetic potential The fertility of the boar used, condition and feeding level at breeding, time during estrus when the dam was bred, feeding level during pregnancy, incidence of disease, or possibility of mechanical injury—any or all of these could have severely limited litter size It is *possible* that a gilt in a small litter could have inherited a *high* genetic potential for prolificness

The heritability values for type or conformation score (or "type classification' in dairy cattle) are not usually high This may be surprising, especially since much selection of breeding stock is done *visually* and there has been considerable emphasis on "type" in the showring Remember that heritability values are calculated, usually from data which show how much more closely relatives appear or perform than do nonrelatives Data may be actual weights, carcass measurements, etc, but for type sconog the scores are *subjective*

A scale will measure weight of relatives with a consistent degree of precision But type scores are applied by *people* and might *be influenced* by (1) mental attitude that particular day, (2) other animals seen since the last group or previous generation was scored, (3) angle from which the animal is viewed, (4) hair coat, (5) finish, (6) temperament of the animal etc These factors and others constitute a source of "error" and invariably *lower* the heritability estimate calculated

It is therefore apparent that the *actual* heritability of type or conformation may be higher than the values in Table 15-1 indicate But *remember,* if the man scoring the animals is subjective and makes some errors because of it, *so will you* when you visually select a bull, ram, boar, or breeding female

Feed lot performance of livestock is apparently inherited to a rather high degree Values given in Table 15 1 are from about 30 to 45 for gain and efficiency For animals confined to a feed lot an important part of the environment is *uniform* and contributes less to performance variation, so

hereditary variation would be relatively *more* important. In general, animals confined to feed lots are *all* fed high energy rations designed for fast gains and relatively quick marketing. Note that heritability of post-weaning pasture gains of beef cattle is only about two-thirds as high as heritability of feed lot gains.

Milk production, butterfat percentage, and related factors are significantly influenced by heredity, though differences in environment—feeding, age at first calving, methods of milking, etc.,—also contribute considerably to the variations in production which exist. Heritability is high enough to indicate that it pays to save heifers from top producing cows.

Variations among carcass traits of meat animals are largely influenced by heredity. Vertebrae number in swine, for example, is established early during embryonic development, giving little time for environmental effects to play a role. The same thing would be generally true for carcass length, leg length, etc., which are primarily a function of skeletal proportions.

The ratio of lean to fat is highly inherited, and this is economically very important. The relatively high heritability of beef tenderness, learned in recent research, may raise some concern over the value of heavy grain feeding of beef cattle (see Section 26.2). Perhaps tenderness can be achieved by selection.

15.4 What if a Trait Is Highly Heritable?

Selection will be effective, and for several reasons. Leanness in hogs is used to illustrate this point.

First, boars and gilts that are lean probably are lean *because* they have genes for leanness. You can pick breeding stock with confidence. The "phenotype" corresponds well with the "genotype." Presumably these

Table 15-2. Summary of Performance Record of University of Kentucky Hampshire Herd*

Item	1951	1954	1956	1958	1960
Number of litters	19	25	48	20	35
Av. number of pigs farrowed	9.00	9.30	10.20	11.00	11.30
Av. birth weight, lbs.	3.10	2.80	2.73	2.87	3.04
Av. number of pigs weaned	7.60	7.90	7.80	9.75	9.30
Av. 56-day weight, lbs.	29.00	31.70	34.10	36.38	37.40
Av. daily gain, lbs. (weaning to 200 lbs.)	1.56	1.68	1.59	1.51	1.50
Feed per 100 lbs. gain, lbs.	374.60	364.50	358.60	346.33	338.11
Av. backfat thickness, in.	1.77	1.61	1.47	1.38	1.35
Av. body length, in.	28.80	29.00	29.30	29.33	29.41
Lean cuts, per cent of carcass	52.60	54.40	55.68	56.39	57.83
Av. loin eye area, sq. in.	4.71	4.83	4.50	4.38	4.45
U.S. No. 1 carcasses, per cent	55.30	83.00	89.60	95.00	98.50

*C. E. Barnhart *et al.*, *Report of Annual Livestock Field Day*, University of Kentucky, Lexington, 1961.

'lean' genes will be transmitted to the offspring and will be a major influence in *causing* the offspring to be lean The phenotype of the offspring will also correspond well to the genotype In other words, if heritability of a trait is high, potential breeding animals *with* that trait will be *good breeders* for that trait—they ll tend to put that trait in their offspring

Since selection is very effective, you can make *rapid progress* by selection This is especially true in hogs (or poultry) where reproductive rate is high (Table 15-2)

We'll go one step further If the trait you are selecting for is highly heritable and *economically important* you can afford to pay well for a ram, bull, or boar that *has* the trait He will bring you quick and high return on your investment, if used effectively

15.5 What if a Trait is Low in Heritability?

Environment *masks* the genotype It is difficult to select herd or flock replacements with confidence Though a ewe may have been born a single, she may have genes for high prolificness How is a breeder to distinguish between her and another ewe born a single and *without* genes for high prolificness?

Once breeding animals are selected and mated, individual offspring will not perform so closely to their genotype Environmental factors will mask the genotype here, too

So in effect, selection is *less* effective and improvement by selection is *much slower*

Where heritability of a trait is low, this means the breeder might spend less time, effort, and money on bull, ram, or boar selection, but spend *more* time, effort, and money trying to improve the environment For high prolificness he should follow rigid sanitation practices, check sires for fertility, feed for top reproduction (Chapter 11), provide adequate facilities, and *be there* at farrowing calving or lambing time

Even yet, it may be difficult for the reader to appreciate that prolificness in farm animals is primarily controlled by environment and little influenced by heredity Most farmers can cite numerous cases where gilts or boars from large litters beget large litters—where selection for prolificness was *apparently* effective But realize that the average livestock producer who selects rigidly and carefully is *also* a *top notch manager* and *caretaker*

Breeders who have ear notched thousands of pigs and consistently selected for litter size might disbelieve recent research demonstrating that much of the improvement that has occurred in litter size was *automatic* and would have happened without conscious selection On any farm where there might be an equal number of large and small litters, there would be automatic selection for prolificness With absolutely no conscious selection, and gilts being saved for the breeding herd *at random* more gilts from

large litters would be saved—*there are more of them!* The same would be true for other species—dairy and beef cattle, sheep, or poultry.

Ceasing to select for prolificness in farm livestock is not being suggested here. If a cow calves every 12 months, you *know* she has the genetic potential (genotype) for relatively high prolificness. If a ewe gives birth to twins or triplets, she too has a high genetic potential for prolificness. So does a sow that farrows 15 pigs. And these genes can likely be transmitted to the offspring. So if environment can be made and kept optimum, selection for prolificness *can* be worthwhile.

Probably one reason that heritabilities of reproductive traits are low is that natural selection has, over time, developed species or breeds whose reproductive rates are compatible with the environment in which they are normally raised. This may seem a bit theoretical, but is reasonable. If this has occurred, a large percentage of animals have a genetic potential for prolificness *close* to the *optimum*. This means there is relatively *little* genetic variation; most variation in prolificness has *environmental* causes.

15.6 How to Make Heritability Higher

A livestock breeder wants selection to be effective so he can make rapid improvement. He can increase rate of improvement by raising heritability—eliminating all possible environmental variations so that differences in performance or traits of prospective breeding animals will be primarily hereditary.

Selection *within* herds or flocks on a single farm or ranch, where all prospective breeding animals receive the same feed, housing, and care, takes advantage of this phenomena. But when the task is the purchase of a sire from one of several breeders, in different areas, using different feeding programs, with varying facilities, and where other unknown variations exist, it is almost impossible to know whether the differences noted among animals are due primarily to inheritance or to environment.

A relatively effective solution has been the development of swine, beef, and sheep testing stations (see Figure 14-5). In these stations, all pens and facilities are identical. All animals are fed the same rations, from standard beginning weights. Every effort is made to *minimize* environmental variations that might affect animals. Prospective purchasers (and owners) can be relatively sure that the animals performing the best in certain traits have the most good genes for these traits and can transmit them to their offspring.

Where it is not possible to bring prospective breeding animals to a central testing station efforts are sometimes made to standardize environment among farms where they are raised. All breeders in a specific program might agree to a standard feeding trial. They would all use similar rations, start animals on feed at the same age or weight, conclude the test at the

same age or weight, and make the same kinds of measurements and observations Some environmental variations still exist, but they are *reduced* and *more* of the variation in performance is due to heredity, so effectiveness of selection is improved somewhat

In dairy cattle it is common to mathematically adjust production for certain environmental variations known to have influence Age at calving, season of calving, times milked per day, length of lactation, and other factors affect production to varying degrees Detailed records have disclosed how much (see Chapter 29) Since these factors are "environmental" factors, minimizing their effects on records by mathematical adjustments makes heritability higher and selection for production more effective

APPRAISAL OF BREEDING STOCK

Four rules for effective improvement of livestock by selection were given in Section 14.6. Rule Number 3 was: Observe or measure accurately the traits carried by a prospective breeding animal. This chapter includes how the important traits can be appraised, with the *eye* and by means of certain *measuring* techniques. Some traits can be accurately evaluated by the eye; others cannot. Currently employed measuring techniques also have limitations (Figure 16-1).

While reading Chapter 16 keep in mind an important point emphasized in the previous chapter—if environment is uniform, phenotype will be a better indicator of genotype and heritability of traits will be higher. In other words, if all prospective breeding animals are fed and handled as nearly alike as possible, it will be easier to identify the animal or animals with the best traits. Both the eye and measuring techniques can be more effectively and accurately used for selecting the best herd or flock replacements.

Though some of the points discussed in this chapter are also applicable to dairy cattle, most emphasis is on meat animals. Chapter 29 is devoted to appraisal of dairy cattle for milk production.

16.1 The Traits Desired

Health is obviously a primary consideration in selection of breeding animals. Poor health, whether resulting from injury, contagious disease, or malnutrition, will impair productive and reproductive efficiency. All new breeding animals should be blood tested or certified to be free of reproductive diseases. These diseases can be spread very rapidly, especially when animals are bred by natural service.

Any addition to a flock or herd should be *prolific*. Females should come in heat regularly, shed sufficient number of ova, and settle quickly. Bulls, boars, and rams should be masculine and aggressive. They should produce a sufficient volume of semen with a high concentration of normal, healthy, long-living sperm.

In most cases a potentially *long life* is important. After a ewe reaches two years of age, she is of little value for slaughter. (Compare current

Figure 16-1. Some of these heifers should be saved for the breeding herd They will be more profitable They will produce more calves that will be heavier at birth and weaning and will gain faster in the feed lot. Which ones? (American Shorthorn Assn)

prices of fat lambs and mature ewes for slaughter) Yet, considerable investment has been made to grow her to breeding age For maximum profit to the flock owner, then, she must produce a large number of lambs before she dies. Ten-year-old ewes are not uncommon in well-managed midwestern flocks. In range flocks, few ewes are kept after they reach seven or eight years of age.

A similar situation exists in beef herds Heifers are usually two to three years of age before they calve the first time. Since the slaughter value of a mature animal is lower and the expense of raising the heifer to breeding age is large, cost per calf is tremendous if the heifer produces only three or four calves during her lifetime.

In swine, longevity is not so important. Gilts usually farrow first at about one year of age and again at 18 months The relative cost of raising the gilt to breeding age is less because she is sexually mature earlier. Secondly, she produces litters—usually seven or more offspring—rather than singles or twins. A third important factor is that the value of the carcass from a two year old gilt (most are sold for slaughter after weaning the second litter) is little less, per pound, then the value of a carcass from a six month old gilt.

Efficient growth is important. Feed represents 60 to 90 per cent of the cost in livestock enterprises Animals that utilize feed more efficiently are more profitable.

Quality of product is another major consideration. For a rancher the product may be feeder lambs or feeder calves—though the ultimate product for all meat animals is a carcass Because many aspects of carcass quality are so highly inherited (Table 15-1) a breeder should select sires or dams that would themselves yield high quality carcasses Well muscled animals with a high proportion of high-priced cuts should be selected. A detailed discussion of desirable carcass traits is given in Chapter 23.

Wool is an important product for the sheep raiser. Amount and quality of wool are largely determined by heredity.

Which of the above traits is *most* important? The trait which will contribute most to long-term profit is most important, but that trait may not be the same for all situations. Here is why.

1. Traits desired in a sire may be influenced by traits already present in the female herd or flock. A farmer with sows that are prolific, lean, and meaty, but which gain slowly, would probably emphasize growth rate when selecting a boar.
2. Some traits are desired *in the animal being selected*, as well as in its offspring. Prolificness, longevity, and feed efficiency are examples. Other traits need to be demonstrated *only* in the *offspring*—rate of gain, carcass quality, etc.
3. For traits where demonstration of the characteristic in the offspring is important, *heritability* of the trait should be considered. If the trait is *not* inherited and influenced solely by environment (and its demonstration in the animal being selected does not contribute directly to profit) then it is not an important trait to consider in selection. If, however, the trait is highly inherited, it would be *very* important in potential breeding animals.
4. How many offspring will the selected breeding animal have? A selected heifer, ewe, or gilt transmits genes to relatively few offspring in her lifetime. A bull, ram, or boar, however, may sire hundreds or thousands of offspring. This doesn't influence *which* trait is most important, but it does influence *how much more important* a trait, desired and carried by the sire, is.

A. How Accurate is the Eye?

Much improvement in the livestock herds and flocks of the world has been accomplished in past centuries by visual selection of superior breeding animals. Visual appraisal has been supplemented considerably, however, by *accurate observation of performing ability*. Skilled and experienced livestock raisers are very observing and they have a good memory.

A good beef herd owner remembers the heifer or cow that doesn't settle quickly or produces a light, weak calf. He makes it a point to cull her and not save her offspring for the breeding herd. A hog man will note the gilt that grows faster than the rest because she may "stand out," and he will keep her for the herd. A sheep rancher will tend to save the lambs which grow and mature faster, and that are from a ewe that produces a dense, heavy fleece of high quality wool.

Successful livestock raisers, who have improved their herds and flocks by selection, realize that it takes much experience, practice, and training to make *accurate* visual observations. The memory must be trained, too. A breeder who looks at four different boars on four different farms must be able to visualize the animals if he wishes to base his decision, in part, on type and conformation.

Table 16 1. Accuracy of the Eye in Appraising Traits of Breeding Animals

A Traits accurately observed	Straightness of legs and feet
Color	Width
Horns	Meatiness
Number of teats	Spring of rib
Physical defects	Tendency to fatten
B Traits less accurately observed	Teat placement
Mature size (if mature when observed)	Temperament
Face covering in sheep	C. Traits observed with poor accuracy
Age	Prolificness
Weight for age	Longevity of production
Wool density	Feed efficiency
Wool quality	Marbling
	Tenderness

The eye can be very accurate and precise in appraising certain traits Table 16-1 lists some of the traits that are considered in appraising breeding stock, roughly grouped according to the ability of the human eye to appraise them accurately

16.2 Traits Accurately Observed

A few traits can be appraised by the naked eye with almost perfect accuracy and repeatability Color, presence or absence of horns, number of teats, and a few others are such traits They are either "there" or not They look the same in the morning or evening—today or tomorrow They look the same to you as to me Few mistakes can be made when selecting for these traits, unless the breeder is color blind or can't count

Of course, accurate appraisal of the trait as it exists doesn't always disclose the complete genotype A polled bull may carry a gene for horns, as illustrated in Chapter 14, or a black cow may carry the gene for red color

16.3 Traits Less Accurately Observed

Many of the traits listed in the middle section of Table 16-1 are relatively "subjective" A boar may look older to one person than to another Appraisal of conformation points—width, depth, straightness of legs, etc —may vary depending on what the appraiser considers to be "ideal" The attitude of the appraiser may influence his evaluation of an animal He may rate it low if he is irritated and in a critical mood

Quality of the entire crop of lambs and degree of uniformity may influence the breeder's evaluation of top ewes being considered for replacements If the good lambs are surrounded by narrow, light lambs, the good ones will appear excellent If, however, the crop is relatively uniform, the breeder may feel the good ewes are "just above average"

An animal that has been ill or poorly fed will probably not rate as high as one in top condition, even though it may have more desirable basic conformation—width, straightness of legs, muscling, etc. The fact that most who show breeding animals in competition usually have them in high condition (very fat, often much too fat for breeding) is sufficient evidence that condition influences visual appraisal.

A nervous and unruly heifer, in a group being sorted to yield replacements, will often be discounted more than the nervousness exhibited would warrant.

The above illustrations merely point out that traits which can't be *objectively* counted or appraised don't look the same to all people, on successive days, or under varying circumstances. But experienced and observing livestock raisers use certain clues to improve their accuracy in appraising subjective traits.

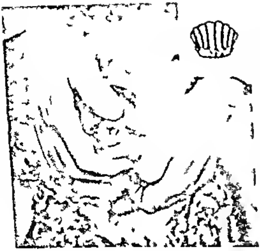
Age can be closely estimated by looking at the teeth (Figure 16-2). Animals within a species tend to lose their temporary incisors at rather uniform ages, usually varying less than three months. Age can also be estimated, by an experienced livestock raiser, by noting the size of head, the length of ears and tail, and length of legs. Remember that the skeleton has priority over lean and fat tissue in receiving nutrients for growth, so tends to grow at a rather consistent and uniform rate. A breeder may starve a gilt so she will appear lean at 200 pounds, implying that she is genetically lean. A careful buyer, however, will note the longer tail, legs, and head, and perhaps suspect that she is light for her age. He then deduces that she either "did very poorly" or was purposely underfed.

There are several important traits in sheep which can be rather accurately appraised by the eye of an experienced and skilled sheep raiser. Wool density and length, which influence amount of wool produced per year, and wool quality (see Section 27.2) can be compared among animals being considered for the flock. Amount of wool covering the face is also apparent. These particular traits are also rather high in heritability (Table 15-1). Appearance is a good indicator of genotype so if animals with desired traits are selected they will likely transmit these traits to their lambs.

Accuracy of estimating "weight for age" (rate of gain) obviously depends on the ability to estimate age and weight. Experience is essential in developing the ability to estimate either. Men who weigh livestock daily can become experts at estimating weight.

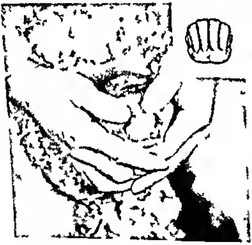
Animals that will be in a herd or flock for many years—females that will carry the load of pregnancy many times and sires that will breed often for many years—need straight, strong, and well-placed legs and feet. A straight leg will support more than one which slants, and for a longer time. There will be less strain on the joints. If legs are placed "out on the corners," less of the body hangs over to create leverage.

Extremely straight or extremely crooked legs are distinguished by anyone, but those between sometimes vary in appearance. Straightness of legs

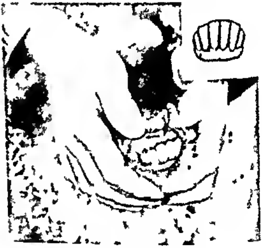


LAMB

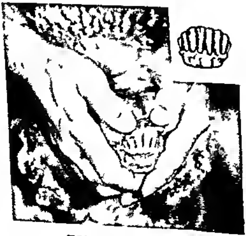
YEARLING



TWO YEAR OLD



THREE YEAR OLD



FOUR YEAR OLD

Figure 16 2 Teeth provide a close estimate of the age of a ewe or ram (Photos Iowa State University drawings Ford Motor Co)

may be influenced by the current weight of the animal and whether it is standing on soil, bedding, or concrete. Also, two people will not necessarily agree, or will one person always agree with himself on successive days, as to the relative straightness of an animal's legs.

Breeders of cattle and sheep prefer an animal with a straight topline. A sagging or "weak" topline is considered undesirable, probably because such an animal may be subjected to more stress by the weight of pregnancy and therefore may not produce for as many years. Some feel a straight topline indicates a large eye muscle (longissimus dorsi) along the backbone, but no evidence to support this opinion is available. In hogs, a slightly arched topline is preferred by some breeders. This is apparently based on the geometric principle employed when arched rafters are used to support a roof over a large open area. Note the pig is longer between the front and hind legs, in relation to over-all size, than cattle or sheep. So the extra strength supplied by an arch of the backbone may be important.

Meatiness, the most important trait from the standpoint of carcass quality of offspring, is discussed in more detail in Section 23.5. It can be estimated similarly in breeding animals by noting width of shoulders and hind legs, bulginess of muscles, and depth of ham, round, or leg. An animal can show good muscling even when it carries little finish. In fact, too much finish often fills in the slack spots and disguises the degree of muscling.

The tendency to fatten is a trait that is often difficult to appraise. This is apparently one of the reasons breeding cattle and sheep are often kept rather fat for showing in competition—to prove to the judge that they carry the ability to fatten. Breeding efficiency of some potentially good sires and dams is actually impaired by such overfeeding. In recent years many objective breeders, who must make their profits from high reproduction efficiency, have refused to show such breeding stock in competition. It is both embarrassing and costly to have a champion breeding heifer that won't conceive.

Most breeders prefer animals that have a spacious thoracic cavity, giving plenty of room for the heart, lungs, and other organs to operate. Hence, they look for animals with a wide chest and with the ribs wide apart—a lot of "spring of rib."

Number of teats is easily determined by counting, but location and prominence is a relative thing. Teats should be far enough apart and large enough so a calf or pig or lamb can nurse without difficulty. Size and prominence of teats is highly inherited, so should be noted when appraising breeding stock, both female and *male*. Inverted nipples, which are difficult to suckle, are rather common in hogs.

The head—its shape and conformation—is used by some as a major indicator of merit in breeding animals. It is logical that a wide, blocky ewe or heifer should also have a head of the same relative shape—wide at the

poll, between the eyes, and at the muzzle Therefore the head does often serve as a fair indicator of conformation But *why spend time evaluating the head when the body is available to see?* Appraisal of the head should serve merely to support impressions of body type and conformation

The upper and lower jaw should mesh, so the animal can graze and chew efficiently An overshot or undershot lower jaw is not uncommon in cattle and sheep

16 4 Traits Observed with Poor Accuracy

Note that the traits listed in the lower section of Table 16-1—prolificness, longevity of production, and feed efficiency—are *very important* traits in a breeding herd or flock They are the major contributors to profit or loss, success or failure and, at the same time, are the traits generally most difficult to appraise with the naked eye

It is probable that some traits mentioned in the previous section, such as straightness of legs and topline, directly or indirectly influence longevity of production Rate of gain usually influences feed efficiency, because faster gaining animals use a smaller proportion of feed for maintenance, the amount of feed consumed per pound of gain is less

Some breeders attempt to appraise prolificness by the "broodiness" a female may demonstrate, though this trait is difficult even to describe Temperament of a heifer, ewe, or gilt may affect net reproduction rate If the dam is restless offspring may be unable to nurse readily and an extremely nervous gilt is more likely to lie on some of her pigs

But it is clear that exterior characteristics do not disclose the number of ova a ewe will shed or the concentration of sperm in a bull's semen The ability of an animal to secrete enzymes which will chemically digest feed, to efficiently absorb released nutrients, and to convert them to tissue are not evident to one who merely looks at the animal

B Simple Measuring Techniques

The inability of the human eye to accurately and precisely appraise economically important traits in prospective breeding animals *at the time they would be selected* indicates the need for using or developing certain measuring techniques which can aid the eye

It is significant to note that measuring devices or record systems which appraise and record the productive merit of an animal not only aid the eye, but also aid the *memory* Perhaps too much credit for past livestock improvement has been given to visual appraisal Considerable credit should be directed to the breeder's memory of previous performance of particular animals or their relatives In a small herd or flock, cared for by the owner

and his family and providing enjoyment as well as income, the breeder may have had an almost perfect memory of the performance of every animal. This was, no doubt, the *major* basis for selection, supplemented by visual appraisal at the time decisions were made.

Such a situation is less likely to be true in the latter half of the twentieth century. Herds and flocks, on the average, are larger. Hired labor is often used to care for the animals. Breeders still enjoy and have pride in their herds or flocks, but they participate in other pleasures and have a wider variety of interests. Their mind is also more concerned with evaluating other information on topics such as fertilizer, pesticides, and feed additives, which are increasingly important. All this means that less time, interest, and attention are usually devoted to being personally acquainted with the performance of every animal and that records to aid the memory are more necessary and worthwhile.

The best measuring techniques or tools are the *simplest*—for they are the ones which will most likely be used by a breeder. A pencil (Section 16.6) and a scale (Section 16.7) are the basic tools for measuring and recording livestock performance.

It must be kept in mind that replacement heifers and lambs are usually selected and sorted out at weaning time, so that they may be grown on pasture or harvested forage, rather than fattened with those intended for market. Gilts are usually sorted out at about 150 pounds or four months. At the time of selection, heifers, gilts, or ewe lambs have not had time to demonstrate certain characteristics which are important and which a breeder wants to consider. Obvious examples are prolificness, milking ability, and length of productive life. The breeder must therefore depend on information provided by some relative, such as dam, sister, or half-sister. The adequacy of such information, in appraising the weanling heifer, ewe lamb, or gilt, depends on the heritability of the trait and the degree of relationship between the animals concerned.

16.5 Identification

Proper identification of all animals is the basis of any complete record keeping and livestock selection program. The breeder may be familiar with every animal, but lack of a positive identification system makes any record-keeping program worthless if he dies or is incapacitated.

Most breed registry organizations require that an animal's registry number be tattooed inside one ear with permanent ink. Some, especially for sheep, also provide small ear tags. Since registration numbers are usually long, most breeders also use some type of private system. Such numbering systems are also used on grade (not purebred) herds or flocks. A common system used in swine herds is illustrated in Figure 16-3.

For easy identification on pasture or range, large numbers can be ap-

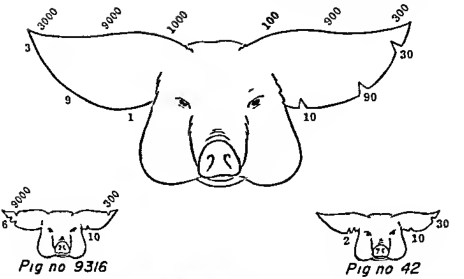


Figure 16-3 Pigs can be numbered by notching the ears soon after birth The above system permits numbering up to 9,999 Special paint used for numbering sheep will not smear in rain, yet will wash out when clipped wool is scoured (Photo, Geo A. Hormel & Co)

plied with special, long-lasting paint or, on cattle and hogs, by hot iron branding.

16.6 The Pencil

Write it down! Birth dates, litter size, and number born dead, as well as environmental stresses such as injury which might later influence your selection decision, can be recorded on the spot in a small pocket notebook (Figure 16-4). Such information can be transferred later to permanent record sheets or books.

Breeders benefit from records showing dates females came in heat and were bred. Late and inconsistent breeders can be detected more easily, and calving, lambing, or farrowing dates can be anticipated with more accuracy.

16.7 The Scale

Birth weight is a guide to the ability of the newborn animal to withstand the stresses it will be subjected to. Animals that are heavier at birth usually gain faster. Experienced livestock raisers can estimate birth weight with considerable accuracy, but a scale weight provides precise information to use later in selection decisions.

Figure 16-4. Easy identification of animals facilitates record keeping This rancher, in the Osage country of Oklahoma, tattoos and ear tags calves at birth, then brands the number at weaning time. The first or last digit may tell the year of birth. (*Successful Farming* Magazine)

Weaning weight is important to livestock breeders for two reasons besides direct value of the weight It indicates the relative milk production of the dam, especially in beef herds and sheep flocks where creep feeding is not practiced and the calf or lamb depends on milk as the major source of nutrients It also discloses, to some degree, the young animal's inherent ability to gain If management, milk supply, and other factors are similar, the animal which gains more rapidly up to weaning time will probably continue to gain more rapidly and will tend to transmit this trait to its offspring

Where hogs are raised in confinement, it is usually feasible to wean all pigs at the same age so weaning weights can be compared directly With beef herds and sheep flocks this is not practical, so adjustment tables or charts have been developed which allow weighing at the same time many calves within a certain age range and adjusting their weights to a standard age (Figure 16-5)

It is also important to adjust the weaning weight of calves or lambs for age of dam, since very young and very old cows and ewes give less milk Single lambs may weigh as much as 10 or 11 pounds more than twins at weaning time in drier range areas where vegetation is sparse In midwestern farm flocks, however, where feed is usually plentiful and lambs are usually creep-fed, the difference may be insignificant

If productivity of dams is being compared to decide if some should be culled, the offspring's weaning weight should also be adjusted for sex Bulls will be about 15 pounds heavier than steers, and steers about 20 pounds heavier than heifers This, too varies among areas

Weaning weight, as a measure of the dam's producing ability, is better than weights recorded later After weaning, the animal's growth is more influenced by feed supply and less by the dam's milking ability

There is a relatively high correlation between weaning weights of calves, lambs, or pigs, and gains during subsequent periods This is especially beneficial in sheep flocks and beef herds where breeders like to select their replacement females early and and sell the remainder as feeders

Some breeders want more precise information especially in evaluating prospective sires Because a sire may transmit genes to hundreds of offspring in a year, it is worthwhile spending more time, money, and effort for precise appraisal of the sire's productive merit

Swine, bull and ram testing stations available for use by many breeders have developed in many sections of the United States (Section 15 6) Some breeders operate their own testing units Such units are designed to measure rate of gain and feed efficiency for a standard period of time after weaning and before breeding age Potential sires from different farms and ranches are more fairly compared at these stations because environment is standard

Most stations operated by livestock organizations require that all animals meet certain growth, feed efficiency, and, perhaps, meatiness standards in

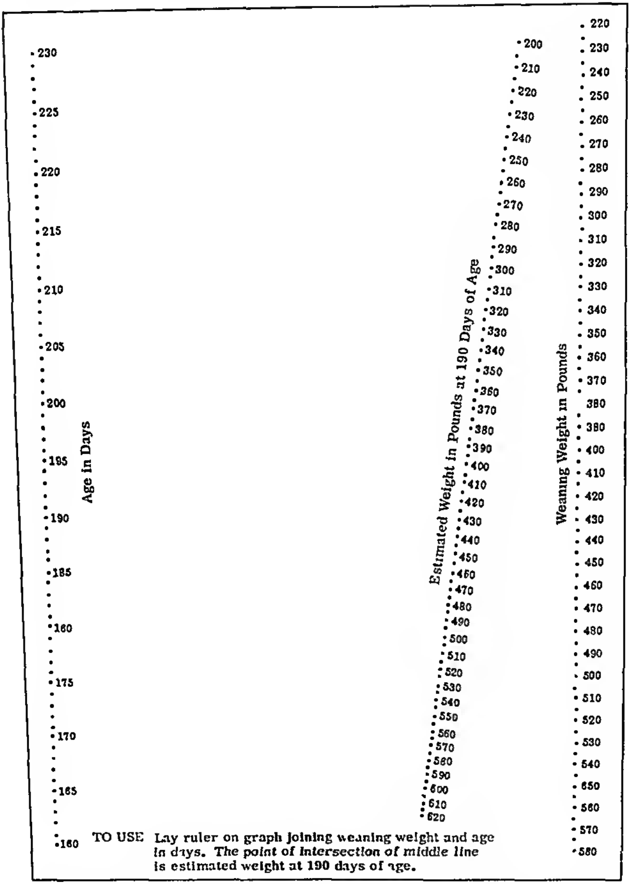
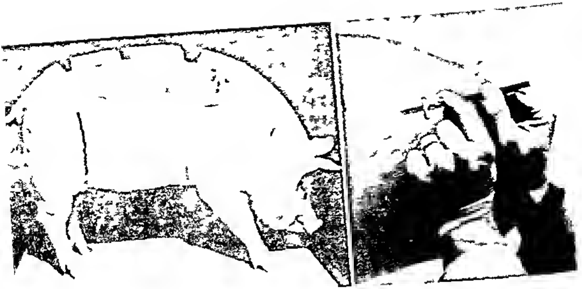
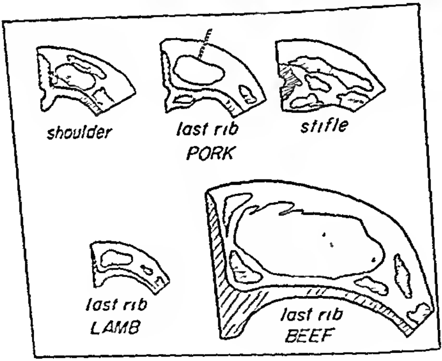


Figure 16-5. Graph used to adjust weaning weights of calves to standard age of 190 days This graph was developed from weight records on calves in Corn Belt herds It may not be usable for other areas Many ranchers develop their own standardization tables or graphs based on performance in their herds




shoulder
last rib
PORK
stifle
last rib
LAMB
last rib
BEEF

conformation traits can be improved by selection at the same time. They are not genetically antagonistic. Obviously, though, less rapid progress will probably be made in one trait if a second is being selected for at the same time.

Wool weights are commonly recorded by progressive sheep raisers, and used as a basis for selection, just as milk production is recorded and used by a dairyman.

16.8 Measuring Meatiness

Carcass data from relatives could be used as a guide to meatiness of potential breeding animals, but is sometimes not available and is of limited value because the relatives are genetically different, to a degree, from the animal in question. Other techniques have been developed to measure directly the meatiness of animals in some species.

A metal ruler (live probe) is used to measure backfat thickness on hogs.[1] Backfat thickness as measured by the probe is highly correlated (—.90 or higher) with the percentage of lean in the carcass. Gilts or boars are probed at about 200 pounds. The skin is cut and the ruler inserted at three points, about two and a half inches off the midline of the pig (Figure 16-6). The ruler penetrates the fat layer easily, but stops at the layer of connective tissue covering the eye muscle. If pigs are probed at some other weight, values can be adjusted to a 200-pound basis.

One reason the probe is such an excellent indicator of percentage of lean is because fat thickness is measured near the middle of the eye muscle. A pig with a shallow, kidney-shaped muscle will have a thicker layer of fat at the measuring site, while one with a bulging muscle will have a thinner fat covering.

The probe is not as accurate an indicator of percentage of lean in beef as it is in pork. The irregular shape of the eye muscle makes it difficult to obtain consistent measurements.

A more complicated instrument which provides similar information is called a "leanmeter." It is battery powered and its operation is based on the difference in electrical conductivity between fat and lean tissue. A needle penetrates the fat and the conductivity of the tissue is recorded on a dial. As the needle passes from fat to lean, this is indicated on the dial and the depth of needle penetration can be measured.[2]

An ultrasonic device—an instrument which emits sound waves and records the time it takes for them to bounce back from a junction between two tissues—has also been used to effectively appraise meatiness in beef

[1] L. N. Hazel and E. A. Kline, *J. Animal Science* 11:313, 1952.

[2] F. N. Andrews and R. M. Whaley, "A Method for the Measurement of Subcutaneous Fat and Muscular Tissues in the Live Animal," Purdue University, Lafayette, Indiana, 1954; and Pearson, A. M., *et al.*, *J. Animal Science*, 16:481, 1957.

cattle and hogs[3] It could also be used for sheep The instrument was originally used as a flaw detector for metal parts, ceramics, etc High frequency sound waves emitted by the machine pass through tissue or material at a certain speed When they reach a break, flaw, or junction with a different tissue or material, some of the waves bounce back By knowing the speed with which the waves move through fat tissue, depth of fat can be measured Research workers at Cornell University[4] have even used the machine to trace the *shape* of the eye muscle, with some degree of accuracy (see also Figure 3-5)

Other measuring techniques can be used, but few yield nearly as much information or are as simple to use as the live probe used on hogs Some have used large calipers to measure width of loin, shoulder, and round, or tape measures to appraise circumference of round But these measurements are usually more difficult to make and are less valuable in estimating muscling

Where it is necessary to use carcass data on relatives to evaluate meatiness of a possible breeding animal, percentage of lean cuts and area of the loin eye cross section are probably the best guides Carcass grade is a rough approximation not a precise measure of merit, so is of limited value

16 9 Appraising Conformation

Conformation traits, which are relatively subjective and which were discussed in Section 16 3 as being observed by the eye with less accuracy, are still *important* and must be appraised in prospective breeding animals with all the accuracy that can be mustered

Some breeders use a *committee* of two or three experienced livestock men who score conformation of heifers or ewe lambs by means of some *numerical* system (Figure 16 7) This can be done at weaning time, as they leave the scale Scoring systems can provide as many quality groups as desired A verbal description for each group is usually developed and appraisers try to "set their sights" together

A committee adds validity Conformation scores can be averaged and committee members serve as a check on each other One committee member may have viewed a heifer from the downhill side, so she looked too long legged another may have an exceptionally strong bias against some trait, such as a weak topline, and unconsciously score a heifer with a weak topline too low in all other traits

Though longevity of production is less important in swine herds and relative meatiness can be appraised with the probe, certain conformation items are important and committee appraisal can be advantageous in gilt selection

[3] L N Hazel and E. A Kline *J Animal Science* 18 815 1959

[4] J R. Stouffer *et al* *J Animal Science* 18 1483, 1959

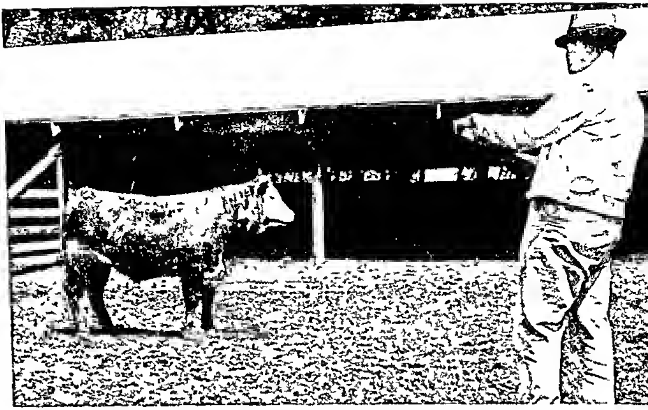


Figure 16-7. Committee members independently grade calves to the nearest one third of a grade (see Figure 16-9) (Iowa State University)

After conformation scores are assigned and weights recorded and adjusted, a breeder will probably do the selecting "on paper" Naturally he will have previously eliminated animals that are chronically ill, or have certain traits definitely not wanted (such as color markings in a purebred herd or flock that will not allow registry). Selecting on paper prevents the breeder from influencing his decision because of personal, subjective bias. To some, this may seem absurd, but *it happens* For example, he may hate to eliminate a particularly affectionate calf, lamb, or gilt, and really hate to keep one that is a bit independent or aggressive.

16.10 Appraising Other Traits

For some reason, points of conformation have a certain esthetic value to livestock raisers. In other words, such things as depth, straightness of legs and topline, and features of the head often have "beauty" to the breeder far beyond their true economic importance Other traits, though also subjective in nature, can usually be more objectively appraised Wool quality, teat placement and prominence, size of udder, etc, apparently have little esthetic value and breeders can scrutinize them with extreme objectivity.

A breeder can check quickly to see if the teats are spaced so offspring can nurse with ease, and to see that no teats are inverted An experienced sheep raiser becomes skilled at appraising wool quality. Samples of wool grades can be compared with the wool on the lamb

Sperm concentration in bull, ram, or boar semen can be checked by

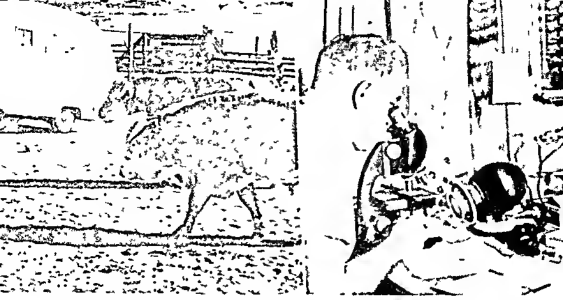


Figure 16-8. A mobile lab for checking sperm number and vigor in bull semen, owned and operated by Colorado State University (*Successful Farming* Magazine)

counting, with the aid of a microscope, as blood cells are counted. Other techniques are available to appraise sperm health and activity, as well as the percentage of abnormal sperm (Figure 16-8)

16.11 Indexes

How can the *net merit* of prospective breeding animals be established? How can the candidates for herd or flock sire or replacement female, since they vary in *all* traits, be fairly compared?

Indexes, which are actually a net merit score, can be calculated, considering the *relative economic importance* of the traits as well as their *heritability* (see Section 16 1). Separate indexes may be calculated for different herds or flocks, or different years, as the relative importance of the traits may vary.

The index for boars which complete the testing program at the Iowa Swine Testing Station has been calculated as follows:

INDEX = 240 + av daily gain (50) − feed per lb gain (50) − probe (50).

In the above index, rate of gain, feed efficiency, and backfat thickness (probe) are given equal emphasis This index was developed, considering feed costs, market differential for lean vs. fat hogs, and the heritability of the various traits (Table 15-1). The factor, 240, is included so a good quality boar will index above 100. A boar that gains 2.2 pounds per day, on 2 9 pounds of feed per pound of gain, and probes 1.4 inches at 200 pounds will index 135.

Obviously a different index, emphasizing leanness more, would be used if there were a larger price advantage for producing lean pork carcasses or if feed and labor were cheap enough that rate and efficiency of gain were less important.

Also recognize that a breeder who already has a group of lean sows may ignore the index and base his selection mainly on growth rate and feed efficiency.

Rather than using indexes, breeders may employ other techniques to arrive at a selection decision. A sheep rancher who wants to save 25 of his 100 ewe lambs may first select the top half on conformation, then save only the half of these that gained faster.

A breeder also might use a selection sheet like that in Figure 16-9. Since about 40 per cent of the heifers must be selected in order to maintain herd size, there is a limit to the severity of selection.

Figure 16-9. A selection sheet for heifer calves at weaning time. After weights are adjusted and conformation scores recorded, all potential herd replacements are entered, by number, on this sheet. A selection line can be drawn according to what the breeder's goals are. Though the heifers aren't "feeders," feeder grades are used as a description of conformation.

Heifers 10-5-61	CONFORMATION GRADE & SCORE														
	Fancy			Choice			Good			Medium			Cull		
Weight	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
500 +			34												
490-500		11		33		42 12				23					
480-490	36							32							
470-480			43		22		38			13					
460-470	35				40				48			46			
450-460				37		27	14							18	
440-450	15		28							47					
430-440		30		16			29	culling line							
420-430							17								
410-420				44	39					26					
400-410									45						
390-400		16										19			
380-390								49							
370-380				51							50				
360-370	21					25			24						
350-360															
340-350			52								31				
330-340															
320-330				20											

C. Culling

Appraisal of breeding animals must continue, even after they have entered the herd or flock. An animal must prove to be a money-maker and must continue as such to justify its place in the herd or flock. Poultry owners cull their flocks daily, sorting out those birds which aren't laying at a sufficiently high level. This same kind of culling can take place with livestock, where merited, and where the breeder has sufficient information to justify culling. Recognize that when heifers, ewes, or gilts are selected for breeding at a rather young age, some mistakes in selection will be made. The real productive ability is not *known* at that age and guides used for selecting are sometimes misleading.

16.12 How Soon Can You Cull?

Can a breeder cull with confidence at the end of the first season? Is the first season's production of a heifer, gilt, or ewe a good indication of her later production? This depends on the trait. The approximate repeatabilities for various traits are given in Table 16-2. Repeatability is the degree to which an animal repeats herself in productivity in successive years or seasons. Since the repeatability varies for different traits, the speed with which a breeder can cull with confidence also varies according to the trait being considered in culling.

Table 16-2. Approximate Repeatability of Productive Traits in Livestock*

Trait	Beef cattle	Sheep	Swine
Birth weight of offspring	.30		
Reproduction efficiency	.10		
Weaning weight of offspring*	.34 (210 days) .35 (112 days)	.20	.10-.16
Grade of offspring at weaning	.22		
Annual wool production		.50-.60	

*Doyle Chambers et al., *Oklahoma Agr. Exp. Sta. Misc. Pub. 45*, 1956, 30.

The true meaning of the repeatability values in Table 16-2 can be illustrated by showing how the repeatability figure of .34 for 210-day weaning weights of beef cattle was calculated. A herd of more than 300 cows at the Oklahoma Experiment Station was divided equally into two groups, based on weaning weight of their first calf (see Figure 16-10). Then the weights of all subsequent calves of each group were averaged.

If the subsequent calves from the high group had averaged exactly 68 pounds heavier than the subsequent calves from the low group, repeatability would have been 1.00. This means the breeder could have culled

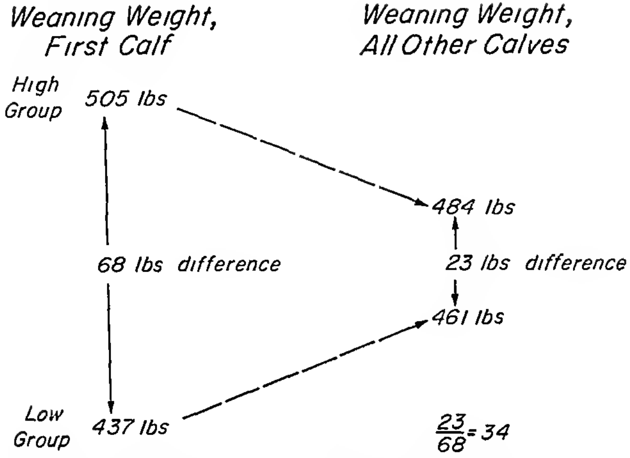


Figure 16-10 How repeatability of weaning weight was calculated using weaning weights of calves from 303 cows at the Oklahoma Agricultural Experiment Station Chambers Doyle *et al* (*Oklahoma Agr Exp Sta Misc Pub 45* p 30 1956)

after the first calf crop was weaned and be *sure* he did right If both subsequent groups of calves had averaged the same, repeatability would be zero, the breeder could not have culled on the basis of weaning weight of the first calf with any degree of confidence The repeatability value of 34 tells a breeder that he can cull the extremely low heifers after one season, but he should wait until the second year for those which might be "borderline"

The repeatability of 35 for 112 day weaning weight tells a breeder that he can cull heifers as effectively when their calves are 112 days of age This may be important, since heifers to be culled need not be rebred (see discussion on practicability of culling heifers in following Section, 16 13).

Repeatabilities of reproducing interval, tendency to settle at first service, tendency for heifers to calve once every 12 months, etc, are usually high enough that when a heifer, ewe, or gilt doesn't settle the first breeding season, she probably should be sold for slaughter The cost of maintaining a heifer or ewe a year is too great and the chances they will conceive later are too poor With multiple or continuous farrowing, gilts needn't be maintained a year, but a gilt that won't settle after two or three services to a fertile boar probably should be culled

16.13 Can You Afford to Cull?

It is apparent that an animal must be profitable in order to justify its position in a herd or flock. The previous section discussed how soon an animal in the herd or flock can be culled with confidence. Certainly females that will not readily conceive and sires that are low in fertility should be culled immediately. But can a livestock raiser *afford* to cull a heifer because she is a poor milker and her calves are rather light and thin at weaning? Can a sheep breeder afford to cull a ewe because she produces only singles rather than twins? The answer to either question is probably "no."

The cost of raising the female to breeding age is so great and the salvage value of a mature ewe or heifer is low enough that it may be practical to keep such heifers and ewes in the herd or flock throughout their productive lifetime. There are obviously exceptions, such as a heifer that calves at two or two and one half years of age and which can be sold at a time when beef prices are unusually high.

As discussed in Section 16.1, with the topic longevity, the problem is not so critical in swine where gilts reproduce earlier in life and their salvage value is relatively higher.

17

RATE OF IMPROVEMENT

Livestock improvement by selection and breeding programs is a slow and tedious process. The one major consolation is that improvement achieved by selection is *permanent* improvement and monetary benefits may be realized for many later generations. Yet breeders, who are in the business of supplying seed stock to commercial producers, want to make improvement as rapidly as possible.

The breeder who can change the characteristic of his herd or flock most rapidly, to provide the type of breeding stock demanded by the commercial producer, will have a good market for his bulls, rams, boars, or even breeding females. When the percentage of lean in pork carcasses became so important to commercial hog raisers, the demand for "meat-type" boars soared. Those breeders who were alert to this demand and used most effective techniques for improvement prospered.

Remember the four rules for effective improvement—(1) have maximum genetic variation, (2) spend selection efforts on traits highly heritable, (3) observe or measure accurately the traits, and (4) use the selected animal most effectively. This chapter discusses the influence of *reproduction rate* on improvement speed, and also Rule No. 4, ways to use the selected animal or animals most effectively.

17.1 Reproductive Cycle and Prolificness

Corn and small grain breeders are envied by livestock breeders in their attempt to improve livestock. The characteristics of a corn or small grain population can be changed rapidly. Two parent kernels can produce 700 to 2000 offspring (kernels) each generation. Two crops (generations) can be grown in one season, by taking advantage of semitropical climates. Think how fast selected traits can be reproduced! Assuming only one ear of corn with 800 kernels was selected for a new "line" or "strain" and that succeeding generations produced only one such ear per stalk, two years' reproduction could result in 327,680 billion descendants available for planting on farms. The opportunity for *rigid selection* and *rapid duplication* of selected genes is tremendous, compared to livestock.

Rapid progress can likewise be made in poultry. Each breeding hen is

capable of producing about 225 chicks per year half of which would be females Each rooster could sire thousands A complete generation passes every year or perhaps in only seven to eight months This explains the rapid development of specialized strains of layers and broilers in the chicken industry and the equally rapid use of these strains to replace traditional breeds Selection can be for *only the best* and when the best are found they can be rapidly multiplied

Hogs are the most prolific of large animals on farms Sows normally farrow first at one year of age thereby completing one generation and they can produce two litters per year If the average litter size is eight pigs this means a selected gilt will beget on the average four gilts and four boars at one year of age and four gilts and four boars at 18 months

The potential offspring of a selected boar might also be calculated Two years after a boar is selected assuming normal use and natural service he might have from several hundred to several thousand offspring available for breeding But remember half are boars and half are gilts whereas in corn every kernel can be both a male and female parent

Sheep usually do not lamb until two years of age and twins occur only about 50 per cent of the time even in well managed flocks So a ewe selected now will not have much effect on average quality for several generations or *many years*

How about cattle? Most heifers calve at three years of age (though increasing numbers are bred to calve at two or two and one half years) and the calf crop is usually under 100 per cent Though three years might be considered the theoretical generation time five years is more realistic on the average because of some nonbreeders abortions etc So here improvement by selection is relatively *very slow*

Though reproductive rate is a bottleneck in livestock improvement it is obvious that much improvement has been made over the past century and a number of recent developments may speed improvements by increasing prolificness

17 2 Predicting Rate of Improvement

High heritability of selected traits maximum reach and accurate appraisal of prospective breeding animals will all contribute to rapid improvement The effects of heritability on the speed of improvements by selection were discussed in Sections 15 4 and 15 5 Reach the difference between animals *selected to be parents* and the *average of that generation* can be greatest if there is much variation within the herd or flock (Section 14 7) and if the animals are selected with care and accuracy (Chapter 16)

Rate of improvement per generation can be predicted with reasonable accuracy by simple calculations After breeding animals have been selected with the greatest accuracy and objectivity possible multiply the heritability

A Weaning weight of beef cattle

Av weaning weight of calves selected for breeding herd	=	525 lbs
Av weaning weight of all calves	=	475 lbs
Reach	=	50 lbs
Heritability	=	20
Predicted improvement	=	10 lbs

Predicted av weaning weight of offspring of selected calves = 475 + 10 = 485 lbs

B Backfat thickness of pigs at 200 pounds

Av of pigs selected for breeding herd	=	1 4 in
Av of all pigs	=	1 8 in
Reach	=	0 4 in
Heritability	=	50
Predicted improvement	-	0 2 in

Predicted av backfat thickness of offspring (at 200 lbs) of selected pigs = 1 8 - 0 2 - 1 6 in

C Milk production of dairy cattle

Av of animals selected to be parents of herd replacements	-	12,000 lbs
Av production of the herd	=	10,000 lbs
Reach	=	2,000 lbs
Heritability	=	30
Predicted improvement	=	600 lbs

Predicted av production of heifers saved for the herd = 10,000 + 600 - 10,600

Figure 17-1 Expected improvement equals 'reach times heritability' Raising either speeds improvement

of the trait times the reach Figure 17-1 provides several hypothetical examples Heritability values were taken from Table 15-1

In examples A and B calculations were relatively simple and direct because the traits, weaning weight of beef cattle and backfat thickness of pigs, are observed directly in the potential breeding animals Averages have, of course, been adjusted for sex, age of dam, or other environmental factors (Section 16 7) and selected males were counted as heavily as selected females in calculation of the averages Remember that bulls or boars transmit half the genes to the offspring

If selection of *only females* were made in Examples A and B, and they were mated to their own sire, reach would be *half* as great and so would expected improvement

In dairy herds all cows are bred and should calve, but only certain heifer calves are saved for the herd Those cows that are selected *to be*

parents of herd replacements (Example C) need not be designated, in most cases, until they have completed at least one lactation

The breeding value of the bull that sires a replacement heifer must, of course, be *estimated* (from production of his dam, sisters, or other daughters) If the sires of the replacement heifers, as well as the dams, in Example C averaged 2000 pounds higher in "breeding value" than the herd average, then the reach given is correct This is certainly feasible where artificial insemination is used and perhaps in some other large herds where several bulls, ranging considerably in breeding value, are used In herds where only one bull is used, however, selection is made only on the basis of the dam's production and reach would be half as great The replacement heifers get only half their genes from the selected dams

To calculate expected improvement *per year,* divide the product of the previous calculations by the number of years which elapse per generation

Livestock breeders also must realize that the improvement achieved by effective selection, as illustrated in Figure 17-1, does not cause a corresponding improvement in *total herd or flock average* The dams of animals *not* saved for breeding *are still in the herd or flock,* with unchanged genetic merit, and contribute to the herd or flock average A dairy cow may produce at the 9000 pound rate (below herd average in Example C, Figure 17-1) so her heifer calves are not saved for replacements But *she* remains

This, in effect, means that average generation interval in sheep flocks and cow herds is considerably *longer* than the time it takes for an animal to produce one lamb or one calf

These examples of predicting improvement rate are given only to show that it can be done Remember that certain circumstances can, in effect, change heritability and slow or speed up improvement

17.3 Successful Improvement

Livestock populations have changed in their characteristics Examples in hogs are more easily found because (1) changes can be more rapid, as previously discussed and (2) goals have changed, several times in some countries

Table 15-2 illustrated changes in the Hampshire herd at the University of Kentucky Though obviously there was possible improvement in environment—feeding management, etc ,—much could have been genetic Figure 17-2 illustrates greater changes in body composition, over a longer period of time, among hogs raised in testing stations in Denmark

Early changes were greatest because there was more room for improvement There was much variation and the reach was probably great Animals *well above* the average could be easily identified, selected, and used

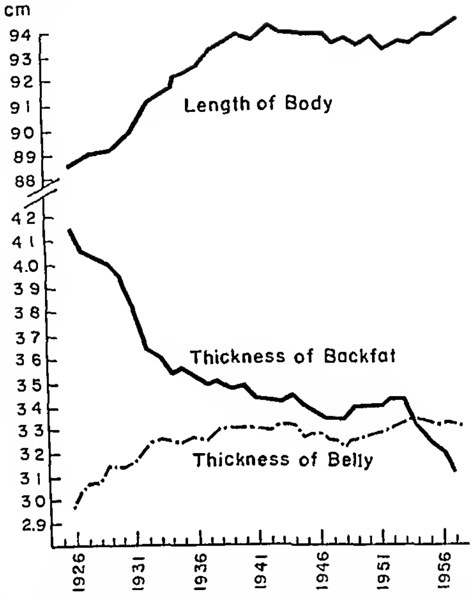


Figure 17-2. Body length, backfat thickness, and belly thickness of Landrace carcasses from the Danish testing station from 1926 to 1957. (Cited by Craft, *J. Ani. Sci.* 17:960.)

As time progressed there was probably less variation and by 1936 breeders were approaching what was considered the optimum body length and backfat thickness. Selection emphasis was then diverted to other economically important traits, such as feed efficiency.

In the early 1950's market standards changed and there was renewed emphasis on carcass length and leanness. Significant changes were still possible, with renewed and rigid selection for these traits.

Remember that body length and backfat thickness are highly heritable. Other traits probably wouldn't have been changed so fast.

Table 17-1 shows the change that was evident among pigs entered in the Iowa Swine Testing Station during successive seasons after it was first used in the spring of 1956.

Table 17-1 Average Performance Data of Pigs at Iowa Swine Testing Station, by Season*

Season	Gain	Feed eff	Boar probe	Index	Carcass length	Barrow backfat	Per cent lean cuts	Loin eye area
56S	1.89	292	1.46	101	29.1	1.64	48.5	3.22
57S	1.80	294	1.24	113	29.2	1.60	50.3	3.40
58S	1.80	285	1.22	118	29.4	1.51	51.4	3.62
59S	1.80	296	1.25	119	29.5	1.50	52.9	3.63
60S	1.77	277	1.19	128	29.3	1.48	53.4	3.77
56F	1.95	303	1.31	109	28.9	1.61	49.8	3.50
57F	1.79	319	1.11	112	29.1	1.51	51.7	3.80
58F	1.76	323	1.19	106	29.1	1.50	52.3	3.81
59F	1.87	297	1.17	125	29.1	1.48	54.3	3.94
60F	1.94	286	1.20	130	29.3	1.61	53.7	3.94

**Fall 1960 Summary*, Iowa Swine Testing Station, Ames, Iowa.

Fall data are separated from spring data for several reasons. Pigs entering the station in the fall have produced leaner carcasses. This may be because the stress of winter slowed gains considerably. Feed efficiency is also lower for the winter-fed pigs.

Note improvement in leanness "within season" has been large, as indicated by lower probe values, less backfat, higher percentage of lean cuts, and larger loin eye area. This change does not necessarily mean that the total hog population of Iowa, or even of the breeders involved, has changed so rapidly. Though the station has permitted identification of muscular boars that have been effectively used to improve leanness in many herds, some of the increased leanness seen in hogs at the station is probably due to improved ability of breeders to *choose* lean pigs to bring to the station for testing. They naturally want to bring pigs that will perform relatively well.

Rate and efficiency of gain declined except for the last two fall seasons. Main selection emphasis during the early years was for leanness so little effort was directed toward gains and efficiency. A possible reason for the decline may have been a changing environment. Incidence of disease organisms may have increased markedly. The station was built in 1955 on what was formerly an alfalfa field. The first group of pigs to come in, in the spring of 1956, had use of clean, relatively disease free facilities. Though good sanitation practices are followed, disease populations do build up over the years as more hogs are brought to the station from many farms and as many people visit the station.

Improvement of beef cattle or sheep by selection is more difficult to demonstrate because of the tremendous *seasonal effect* on performance. Table 17-2, summarizing data from the experimental herd at the Arkansas Agricultural Experiment Station from 1940 to 1960, illustrates this point.

Table 17-2. Changes in Weaning Weights and Conformation Measurements of Calves from Arkansas Hereford Herd, 1940 to 1960*

Year	Mean temperature, degrees F.	Annual rainfall, inches	240-day weight, pounds	Chest depth, inches	Rear flank depth, inches	Width at hips, inches	Heart girth, inches
1940	56.0	40.48	358	18.2	15.7	12.1	48.9
1941	59.9	50.48	383	19.0	16.1	12.3	51.0
1942	58.8	58.88	350	18.7	16.6	11.8	49.8
1943	59.2	40.74	381	18.7	15.7	12.6	50.1
1944	58.7	47.97	384	18.9	16.0	12.9	50.6
1945	57.8	64.23	359	18.6	16.0	12.8	49.8
1946	59.8	52.62	414	18.9	16.4	13.6	53.2
1947	57.8	40.01	444	19.0	16.4	13.8	52.9
1948	58.0	48.28	467	18.7	16.0	13.5	53.3
1949	57.7	47.03	477	19.6	17.2	14.6	53.3
1950	58.9	50.71	453	19.4	16.9	14.6	54.3
1951	57.4	48.13	415	18.4	16.0	13.4	53.3
1952	59.1	34.83	369	17.8	15.2	12.2	50.5
1953	59.7	35.63	372	18.5	15.8	13.1	51.0
1954	60.3	35.33	418	18.5	15.9	13.4	52.1
1955	58.6	37.75	381	18.5	15.7	13.0	50.7
1956	59.1	38.71	341	17.9	15.2	12.2	48.6
1957	57.3	62.51	337	18.2	15.6	12.3	49.1
1958	56.8	45.79	385	18.8	16.0	12.9	51.2
1959	57.5	38.90	367	18.1	15.2	12.6	51.2
1960	56.9	42.81	366	18.3	15.4	12.4	50.7

*C. J. Brown, *Arkansas Agr. Exp. Sta. Bull. 597*, 1958; and from private communication.

Hogs are usually fed a concentrated ration in drylot so environment doesn't vary too much from season to season But weaning weights, type score and other traits of cattle and lambs are greatly influenced by rainfall which controls pasture growth

Careful study of the data indicates steady improvement in weaning weight and conformation traits until 1950 From 1952 to 1956 the drastically lower rainfall and markedly higher average temperature had a very significant effect on performance The herd was moved to a different location in 1952 and managed as part of a more extensive operation This may have influenced performance

How rapidly can improvement in breeding stock be reflected in quality of carcasses sold by commercial feeders? Table 17 3 illustrates both *improvement* and *decline* in carcass quality that resulted when boars were chosen on the basis of *high* or *low* scores of their littermates in feeding and carcass tests on two Eastern Canadian experimental farms A "high" and low boar were initially selected from a previous test then mated to random sows High and Low boar offspring were then successively selected to sire subsequent generations Note the drastic spread in carcass merit

Table 17 3 Grades of Carcasses from Hogs Sired by Boars with High and Low Testing Litter Mates*

Progeny of	1st Generation			2nd Generation			3rd Generation		
	A	B	C	A	B	C	A	B	C
	%	%	%	%	%	%	%	%	%
High boar	66	32	2	69	31		81	19	
Low boar	51	48	1	23	61	16	9	82	9

*Circ 274 Ontario Dept of Agr Toronto

17 4 Efficiency of Natural Service

Most emphasis is placed on sire selection in livestock improvement programs because a selected sire can produce many more offspring than a selected cow ewe or gilt. Also and for this reason the sire selected can be *higher on the scale of merit* than the average of the female replacements that must be saved each generation (Figure 17 3)

In commercial flocks 30 per cent or more of the ewe lambs born each year must be saved just to maintain flock size Should rams be saved from that flock or a different flock of the same general quality less than 10 per cent of the rams need be saved A similar story is true for cattle or hogs

Various guides are printed for the number of sows that should be bred

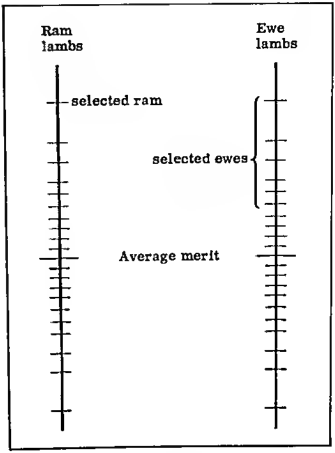


Figure 17-3. Ram selection can be more rigid than ewe selection. So the reach on the sire's side can be larger.

by one boar, cows by one bull, and ewes by one ram (Table 17-4). Such guides may be used, though they do not fit all circumstances. Effectiveness of a bull, ram, or boar depends on his age, size, inherited sexual instincts, sperm production and motility, season, and whether the herd or flock is on pasture or animals in heat are routinely sorted out and put in a breeding pen. Chapters 11 and 13 discussed some of these influences.

Table 17-4. Suggested Services for Boars, Rams, and Bulls in Natural Service

	Services per week		Services per breeding season			
	Boar		Ram	Bull		
	8-12 mos.	Mature	Mature	Yearling	2-yr-old	Mature
Breeding pen	8	12	60	12	30	50
Pasture or range			40	6	15	25

A topnotch sire can be used on more females if those in heat are placed in a breeding pen with the sire for service, than if the sire runs with the entire herd or flock. This, of course, requires more labor, but the increased use of a high quality sire, rather than the additional use of a "second place" male, might be worth the effort. Such practice also facilitates recording of breeding dates so lambing, farrowing, or calving time might be more accurately anticipated.

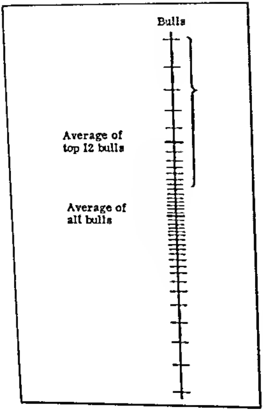


Figure 17-4 Forty bulls from one county, plotted on a "scale of merit" A rancher in Montana with 600 cows and heifers needs 24 bulls if pasture mating is practiced, according to Table 17-4, using them two years Suppose he sets out to buy the best 12 bulls in the county each season from other breeders Note the reach on the sire's side is much higher if he uses artificial insemination and need buy only one

17.5 Artificial Insemination

An ejaculate of semen from a boar, ram, or bull usually contains over a *billion* sperm, most of which are capable of fertilization at the time of ejaculation At conception only one sperm unites with each ovum that is to be fertilized, so obviously there is much waste of sperm in natural service Good bulls, rams, or boars are not used most efficiently

Semen collected for artificial insemination is usually diluted and relatively small quantities are used for insemination, so that a single ejaculate might be used to breed many females The number of females that can be bred varies, depending on semen volume, sperm number and motility, and species, but approximate numbers are six for hogs, 50 for sheep, and 400 for cattle Current research is directed toward further dilution of semen and maintenance of sperm health so that more females might be inseminated per ejaculate

Since semen collections can usually be taken daily, and in some cases twice daily, the number of potential offspring from a top-notch sire is astronomical with artificial insemination And it allows us to reach still further, on the sire's side, each generation in our quest for improved livestock (Figure 17-4)

Naturally the illustration above is a theoretical example, but it illustrates

that artificial insemination does allow more rapid progress in livestock improvement. Though much labor is involved in checking herds and driving in cows that are in heat, artificial breeding is catching on in many range herds. In addition to faster improvement, ranchers have feed for more cows, since fewer bulls are kept.

Dairy herd owners first used artificial breeding on a large scale in the United States, primarily because of ease of detecting cows in heat and of inseminating. The percentage of dairy cows bred by artificial insemination in Iowa increased from about 21 per cent in 1951 to 44 per cent in 1960. In 1961, over one third of the dairy cows in the United States were artificially inseminated. Use has spread to beef cow herds; a significant portion of the business currently being done by artificial insemination organizations in the Midwest is with beef breeds.

Semen can be frozen and stored for months, so the merits of an excellent sire can be "banked" and used even after his death. Frozen semen is routinely shipped long distances, allowing several herd or flock owners to share a bull, boar, or ram.

17.6 Embryo Transplanting

The genetic merit of top quality females in livestock herds and flocks may also be used more efficiently. An excellent cow, ewe, or sow may be allowed to produce more *ova* during her lifetime. Realize that in natural reproduction a prize cow usually has only one ovum conceived per year. She spends three months nursing a previous calf and preparing for the next pregnancy, and the other 9 months pregnant. Is this necessary? Perhaps hormonal treatment could be used to promote production and release of *many* ova, the female be bred, and zygotes later be removed and transplanted to other females which would serve as hosts during pregnancy.

Much research in farm livestock has been directed toward making this technique practical and useful, and a number of successful transplants have been made in sheep, cattle, and rabbits. There are so many problems associated with this procedure, however, that little application of the technique on farms is predicted in the near future.

17.7 Crossbreeding Programs

Crossbreeding as a system of breeding is discussed thoroughly in Section 18.4, but is also mentioned here because it helps speed livestock improvement in some cases. It is another of the techniques breeders employ to make the greatest and most effective use of selected breeding stock. The effect—hybrid vigor (Section 18.5)—is temporary and apparently exists only in the first generation of offspring. It is not a trait that is transmitted to subsequent generations. The benefit is more noticeable in traits associated with general health, prolificness, and livability of offspring.

18

BREEDING PROGRAMS

Mating systems followed by successful livestock breeders vary depending on species, the breeders' goals, and other factors Inbreeding (Section 18 2) is used primarily to develop inbred lines of livestock for later crossing just as in developing corn hybrids Few livestock raisers inbreed within their herds or flocks because of certain risks and disadvantages Crossbreeding, however, is widely used, especially in swine herds and sheep flocks (Sections 18 3 to 18 7)

Various types of mating systems are described in this chapter and the situations in which each might be used most effectively are listed The mating system to be followed often influences boar, ram, or bull selection Once the breeding animals are selected, the mating system or breeding program should make maximum use of their traits, or genes

18 1 Random Mating

The words 'random mating' do *not* imply mating without selection They apply to the way that *selected* rams, bulls, or boars are mated to *selected* ewes, heifers, or gilts

Random mating means that matings of selected breeding stock are not controlled All rams and ewes are kept together and mate at random All bulls run with all the heifers, or all boars mate with gilts at random This is practical if the breeder has no knowledge that certain controlled matings might produce *better* offspring Less labor is required and an entire herd or flock can be handled as a single unit during the breeding season

Obviously, random mating cannot be used in purebred herds and flocks with more than one sire, because both the sire and dam of animals must be known and recorded

Random mating would not be followed if it were apparent that much could be gained by specific matings A commercial Angus raiser in Missouri for example, may raise feeder calves for Corn Belt feed lots, but also will select and keep a certain number of his heifers for replacements Since he naturally wants to improve the quality of his herd, he would probably breed his *best* bull to his *best* cows to get topnotch replacement heifers Resulting heifers would probably be noticeably better than heifers

that could have been selected under random mating. The bull calves born from these matings might be good enough to sell to another breeder, or, if castrated, bring top price as fancy feeders.

18.2 Inbreeding

Inbreeding is defined as mating relatives. The more closely the sire and dam are related, the greater the degree of inbreeding. Many species of plants can be self-pollinated, giving the highest degree of inbreeding possible. Inbreeding cannot be that extreme in farm animals; maximum inbreeding in a herd or flock of livestock would be continued brother-sister matings in successive generations. Even this is seldom practiced, however.

Nearly all purebred animals are inbred to some degree. Since matings are confined to registered animals which usually have some common ancestry, any two animals mated would be more closely related than two animals selected at random within the species. A purebred Duroc boar, for example, has some ancestors in common with any Duroc purebred sow to which he might be mated. The common ancestors may be only one or two generations earlier. If so, the degree of inbreeding would be relatively high. If there were no common ancestors closer than five or six generations, the degree of inbreeding would be insignificant.

From a genetic standpoint, relatives are *more likely* to have the *same genes* than animals selected at random within the species. Herein lies the explanation of the reasons for and also the disadvantages or risks of inbreeding.

In general, livestock raisers usually inbreed to *concentrate the good genes* known to be present in an animal or family into certain future offspring. Such offspring are therefore more likely to *be* top quality and also to *beget* top quality offspring. Since they carry many good genes, they will probably transmit many good genes.

A sheep raiser with 25 ewes, for example, may have five excellent ewe lambs selected to use as replacements in his flock. All were sired by an excellent ram. The ewe lambs inherited half of their genes from the ram so their genotypes are probably relatively similar. Since the ram and ewe lambs show excellent traits—gains, wool growth, meaty conformation, etc. —they probably both carry many genes which promote these traits.

If the raiser keeps the same ram and mates him to his own daughters, chances are high that the resulting offspring will be *very* high quality animals. Since there is considerable evidence that the ram and his first daughters both had excellent genotype, chances are very high that, if mated, *their* offspring will inherit *many* of these good genes.

The sheep example above is a specific type of inbreeding called "linebreeding." This is the most common type of inbreeding in most purebred or grade herds and flocks. Once a sire is proven to be excellent, by his own

performance and that of his progeny continued use of him on his progeny tends to concentrate his genes into the line of breeding

The *theoretical* goal of linebreeding is to finally develop a family of animals that carry *only* the good genes and breed true for all traits in subsequent generations A more practical and realistic goal is the development of inbred lines or strains that will *breed true for certain traits* Two lines might be developed for different traits then animals from each line mated to give offspring with both sets of traits (Section 18 4)

Inbreeding is not recommended for most farms and ranches because of certain risks and disadvantages Just as mating relatives tends to concentrate good genes in individual offspring so does it tend to concentrate bad genes that might be present in the family (Figure 18 1)

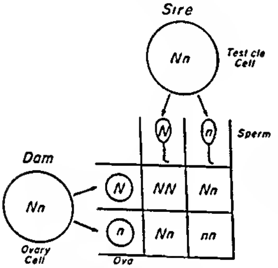


Figure 18 1 Genotype of possible offspring that might result from mating two cattle which carry the dwarf gene If the cow and bull are related they are more likely to have the same genotype They could be brother and sister Note such mating concentrates the good genes (*NN*) in one fourth of the offspring and the bad genes (*nn*) in one fourth

Such bad genes may not all be as detrimental as the dwarf gene, but highly inbred animals are *less vigorous* and *more difficult to raise* They are often smaller in size and more susceptible to diseases and other environmental stresses Also there are specific recessive genes that can cause death or abnormalities when one gene is inherited from each normal appearing parent

Because of the risk involved and difficulty of raising animals of inbred families or lines few producers can profitably develop inbred lines for use on their own farms and ranches Only those breeders who can afford the risk, because of larger size or probability of selling many breeding animals from a relatively pure line find it practical to inbreed In corn and poultry, individual companies have developed many inbred lines, a few companies have developed inbred lines of hogs With cattle and sheep however, development is so slow, because of low prolificness that most inbred lines are developed by state agricultural experiment stations and/or the USDA

It is apparent that inbreeding can be worthwhile *with constant selection*

when the goal is eventual development of an inbred line. Assume the bull and four *Nn* cows (Figure 18-1) are considered the original stock for development of an inbred line. Half of the original genes are *n*. One generation later, after the dwarf is *culled*, one-third of the genes are *n*. Continued mating within this line and *continued culling of dwarf calves* would further reduce the proportion of *n* genes and the line eventually would be relatively true breeding for the *N* gene, having very few *n* genes present.

It is also apparent that inbreeding spreads out a population, giving *more genetic variation*. So culling, and selection, can be easier and more effective.

18.3 Outbreeding

The opposite of inbreeding is outbreeding. Animals to be mated are *less related* than the average of the species, so are likely to have *different* genotypes. "Crossbreeding," where a ewe, cow, or sow is bred by a ram, bull, or boar of a different breed, is the most common example.

Outbreeding may occur *within* a breed. This is called "outcrossing" and is usually done by a breeder for the sole purpose of introducing a desired trait (actually genes for the trait) into his line or herd. Outcrossing may be a temporary interruption in a linebreeding program, practiced when the breeder feels the line he is developing lacks in a certain trait, and that an outcross with another line would provide the trait.

A Hereford breeder in Texas, for example, may be developing a line of cattle with good traits except that they are low in milking ability. He may look to some other line of Herefords, noted for good milk production, for a bull. The use of this bull for several years should gradually increase the average milk producing ability of the herd.

18.4 Crossbreeding

The primary object of crossbreeding is hybrid vigor—the tendency of offspring of a "cross" to perform better in certain traits than the *average of their parents*. The traits which most often demonstrate hybrid vigor, and the genetic basis of this phenomena are presented in Section 18.5.

Crossbreeding may also be done to introduce new traits from some other breed into a commercial herd or flock. An example is the typical ewe flock in the Rocky Mountain area. Most ewe flocks originally were of relatively pure Rambouillet or Merino ancestry. Both are "fine-wool" breeds, and the Rambouillet was developed primarily from the Merino, so they are similar. Being fine-wool breeds, they have been developed with strong selection for heavy production of high quality, fine diameter wool. The high value of wool justified intense selection for wool. Because the rangy Rambouillet ewes were more adapted to the rough terrain, most flocks had little evidence of "meat type" conformation.

In time, wool prices declined. Lambs not needed as flock replacements,

formerly considered a by product of wool production became relatively more important Since lamb feeders prefer blockier lambs that will produce a higher proportion of meaty cuts than typical fine wool sheep it became apparent that such lambs would bring higher prices if they carried some meat type breeding

Flock owners gradually began using more muscular rams—Hampshire Suffolk and others—on many of their ewes The fine wool ewes still produced top quality fleeces but also produced feeder lambs more desirable for feeding Enough ewes were bred to fine wool rams to provide needed flock replacements The genes for meatiness and musceling simply *were not present* in the fine wool breeds to the degree needed

A Midwest farmer with a herd of grade beef cows may occasionally use a Holstein Milking Shorthorn or crossbred bull to provide genes for increased milk producing ability in his future heifer replacements

Hog producers often use a Duroc boar to increase prolificness in later generations a Landrace to increase length or a Poland to increase muscling Other breeds might also be used to provide these or other desired traits

Crossbreeding between or among breeds naturally causes mixed and nonuniform color patterns among offspring This is of no consequence for meat milk wool or egg production Those who still appraise the producing ability of an animal by color patterns or shades have not learned that beauty is only skin deep

18 5 Hybrid Vigor

Crossbred animals—pigs sheep or cattle—tend to be *more vigorous* at and soon after birth and *more resistant* to environmental stresses so they gain faster and are *more prolific* when it is their time to reproduce than the average of their parents (Table 18 1) Hybrid vigor may also be demonstrated in other traits influenced by those above but is not noticeably demonstrated in most body structure and composition characteristics such as carcass composition wool quality and number of teats (If a lean boar is mated to a group of fat sows offspring will be *different from the sow herd* but not because of hybrid vigor They will be about *average between the parents* in carcass characteristics)

Some gilts of each breed in Table 18 1 were mated to boars of every other breed Data for the offspring of these matings are summarized after cross Pure pigs had sires and dams of the single breed

Why *are* crossbred animals usually more vigorous faster gainers and more prolific? The discipline of genetics may provide some explanation

It was previously mentioned that dominance tends to help livestock production Good genes are more likely to be dominant genes bad genes are more likely to be recessive genes Figure 18 2 shows hybrid vigor that

Table 18-1. Influence of Crossbreeding on Weight at Eight Weeks and at Five Months*

Breed	Litter size		Pure or cross	Weight	
	Birth	Weaned		8 weeks	5 months
Berkshire	8.1	6.1	pure	29.9	124
			cross	34.8	157
Duroc	10.3	6.7	pure	36.6	159
			cross	35.8	159
Hampshire	8.7	6.6	pure	31.1	144
			cross	39.6	166
Landrace	8.2	6.3	pure	33.2	150
			cross	38.0	176
Poland	8.0	6.3	pure	37.3	165
			cross	38.4	173
Tanworth	8.9	7.0	pure	31.8	134
			cross	36.5	155
Yorkshire	11.9	10.5	pure	35.2	143
			cross	38.2	150

*L. N. Hazel, Iowa State University.

might result when two hypothetical breeds of hogs are crossed. The example is *extremely over-simplified,* compared to a true situation. The two traits, (1) number of pigs born per litter and (2) percentage surviving at 10 days, are each presumed, only for the purpose of illustration, to be influenced by one pair of genes. The two breeds have been developed, over many generations, by selection for different traits. Breed A has been selected for number of pigs born per litter and is now carrying only the dominant good genes for this trait. No selection has been exerted for survival in Breed A and assume, for now, that the genes carried are recessive and contribute to low survival. In Breed B, the exact opposite is true. Selection for survival has been successful but number of pigs born per litter is small. Take a look at the genotype and phenotype of the offspring.

Figure 18-2. An extreme and oversimplified illustration of the genetic basis for hybrid vigor in hogs. Genotypes are given in parentheses.

	Breed A	Breed B	Crossbred offspring
Number of pigs born per litter	16 (AA)*	4 (aa)	16 (Aa)
Per cent surviving after 10 days	25% (bb)	100% (BB)	100% (Bb)
Number of live pigs at 10 days	4	4	16

*Genotypes are given in parentheses.

In the example above the offspring not only performed better than the *average* of the parents, they performed much better than *either parent* It is emphasized that this is an extremely over-simplified example First, *many pairs of genes* influence each of the traits Second, *variations in environment* do not allow performance to be completely controlled by genotype, especially in prolificness and livability Third, it is unlikely that either breed could have been inbred and developed *to the point* of carrying only good, dominant genes The extreme slowness of developing relatively pure inbred lines was discussed in Section 17 1 And the more gene pairs that are involved, the slower it would be Fourth, it is improbable that each breed would carry *only bad, recessive genes* influencing the trait which was not selected for

Some crosses yield more hybrid vigor than others To really capitalize on hybrid vigor, therefore, it is practical in some species (especially chickens) to develop many lines and make all possible crosses to determine which crosses are most effective and profitable Those lines or breeds which yield, when crossed, most hybrid vigor are then maintained as sources of breeding stock

18 6 Rotation Crossbreeding Programs

In commercial production of "single cross" hybrid corn or hybrid chickens, inbred lines are maintained for *both* parents This is practical because a kernel of corn that serves as a female parent can yield 800 or more offspring An inbred hen can beget 200 to 225 chicks per year And it costs relatively little to produce and maintain a kernel of corn or a pullet

But a heifer of breeding age is expensive She can produce only one calf per year Gilts and ewes are less expensive to raise and more prolific, but still strikingly different from corn or chickens

It becomes obvious that it is *financially impractical* to maintain inbred lines of livestock as a source of *female* breeding stock on farms and ranches Much time and money is involved raising them Only half of the offspring in the line would be females And, too, remember that inbred livestock is *difficult to raise*

The application of crossbreeding to farm livestock production has been primarily in the form of rotational crossbreeding programs Females are raised in the herd Only sires are purchased Such a program can provide much hybrid vigor without extra cost Since more crossbreeding is done in swine, they will be used as an example (Figure 18-3)

The first boar purchased for a rotational crossbreeding program should be relatively unrelated to the foundation gilts, probably of a different breed, and should carry additional good genes for certain traits that need to be improved in the herd (Section 18 4) The first crop of crossbred pigs will be *more vigorous*, if the cross is successful in terms of hybrid

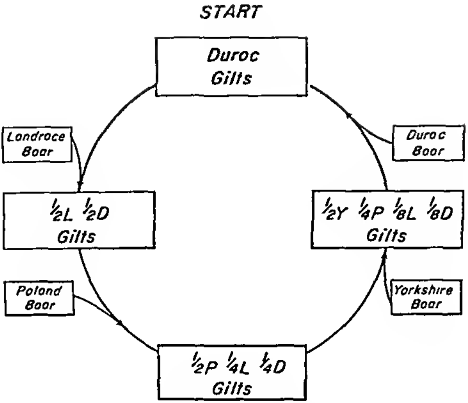


Figure 18-3. A rotational breeding program in a swine herd. Starting with gilts of relatively pure breeding, relatively unrelated boars are used in successive generations.

vigor. More will probably *survive* and they will *gain faster*. When the crossbred gilts reach sexual maturity they will be more prolific and will give more milk. This is a *big advantage* to rotational crossbreeding as compared to maintaining inbred lines for female stock.

The crossbred gilts (50 per cent Landrace: 50 per cent Duroc) are then mated to a purchased boar unrelated to them. This boar (a Poland) is also selected, not only to cause hybrid vigor, but also perhaps to supply some new or additional good genes for certain traits in which the gilts may be lacking. Female offspring of this cross, to be saved for subsequent mating to a Yorkshire boar, are 50 per cent Poland, 25 per cent Duroc, and 25 per cent Landrace.

Gilts sired by the Yorkshire boar contain only 12½ per cent Duroc breeding, so could be mated to a Duroc boar and hybrid vigor would still be expected.

Many who follow such a rotational breeding program in their swine herds employ only three breeds. The gain in hybrid vigor by using the fourth breed is small, and breeders often find it difficult to locate *good* boars, with the traits they want, of four different breeds in their area. It is better to use three good boars in a rotational program and lose a trace of hybrid vigor than to use three good boars and one poor boar.

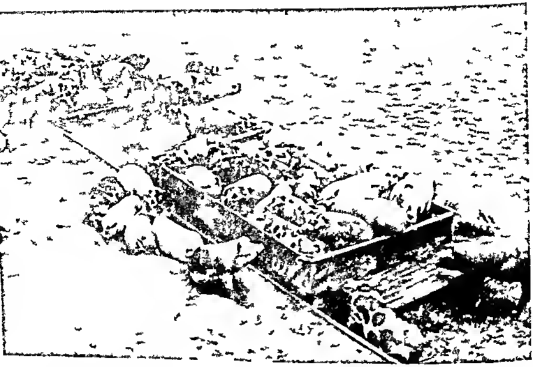


Figure 18-4 Most droves of hogs on farms are largely crossbred and so contain a variety of color patterns (Iowa State University)

Just as sample crosses are made to see which mating will yield most hybrid vigor in single crosses involving only two lines or breeds so do experiment stations use various combinations of lines in rotational programs to see which fit best together and yield most benefit One such program took over 20 years and involved 13 different state experiment stations and the USDA but the result was three specific lines that were *known to work well together* and to *yield maximum hybrid vigor* as well as other desirable traits in their progeny This thorough a program is not always feasible though experience gained early in the 20 year period provided much information that raisers could use in their own crossing programs

Though crossbreeding is routine in market hog production for hybrid vigor and in range sheep flocks for both hybrid vigor and production of better feeder lambs application is not so widespread in beef cattle Benefits at the present time probably would not be so great in beef cattle as in hogs for several reasons (1) Environment is not as great a stress on young calves as on young pigs so improved vigor at birth may not be as advantageous (2) Inbred lines have not been as well developed and tested in crosses and there are few inbred lines at all (3) Some packers and therefore also feeders discriminate against cattle with mixed color markings

Benefits would definitely be worthwhile however because the same principles apply as in hogs and sheep Many beef raisers *are* crossbreeding

Though few inbred lines exist, crossbreeding between breeds or between relatively unrelated families within breeds can be profitable.

Crossbreeding in dairy herds, likewise, is not common. The first and second reasons listed above for beef cattle also apply to dairy cattle. Also, certain breeds may be preferred because of the volume and composition of milk they produce. One specific breed might be used by dairymen in an area where milk is purchased primarily on a volume basis, and another breed preferred where a premium is paid for high butterfat production.

18.7 Will the Advantage of Crossbreeding Continue?

Hybrid vigor, though *influencing* the whole animal, is expressed in a limited number of traits—mostly those related to prolificness, livability, and rate of gain.

Remember that we are continuing to *select* for prolificness, livability, and rate of gain. Crossbreeding is employed only to gain the *greatest possible use of selected animals*. If livestock breeders could ever reach, by selection, the optimum level of prolificness, livability, and other traits promoted by hybrid vigor, then the benefit of crossbreeding for the purpose of attaining hybrid vigor would drop to zero.

Some sheep ranchers in the dry, range country of western Texas do not appreciate twins. Ewes aren't able to graze enough forage most years to provide milk for two. A single lamb has a distinct advantage. So crossbreeding for the sake of increasing prolificness is not advantageous here.

Perhaps *improved shelter and management*—environmental control—will raise prolificness, livability, and rate of gain to an optimum point. Perhaps some of our herds and flocks now have the genetic potential for optimum production if environment were optimum.

It is unlikely that selection will be effective *enough* in the near future to eliminate the benefits of crossbreeding in swine raising. Poultrymen are still crossbreeding, and they are way ahead of the swine raiser in selection achievement. For sheep and cattle, the hope of reaching an optimum level of production by selection alone seems infinitely remote.

19

BREEDS

A breed of livestock is a group of animals that result from breeding and selection and which have distinguisbable characteristics In most cases, selection has been practiced for many generations in order to fix certain characteristics in the breed

It is apparent from historical writings that breeds of livestock once existed that are, for all practical purposes, extinct today These breeds may have reached a certain stage of development, then were crowded out by new and better animals Or, as is known in many cases, several former breeds may have supplied foundation stock for development of a new breed

The reader should be reminded that only since the middle and late 1800 s have most breed registry books been closed to animals whose parents were not registered Before they were closed, genes from other breeds or strains were often introduced into a particular breed in this or other countries by certain matings, in an attempt to improve certain traits of the breed This was certainly a practical thing to do since livestock raisers were more concerned with maximum and efficient production than with extremely uniform color markings

This chapter will not provide a thorough discussion of all of the live stock breeds commonly raised in the United States Rather, it will simply explain why there *are* different breeds, discuss just where present day breeds fit in the chronology of the livestock industry, and briefly discuss the groups of breeds commonly raised in the United States today

19.1 Why Breeds Have Developed

Primarily, breeds have been developed to provide increased production of meat, milk, and/or wool, within a certain environmental area

Livestock producers have observed that some animals were more adapted to certain areas or production situations than others A sheep raiser in the rough, mountainous land of Scotland in the sixteenth or seventeenth century, for example, may have observed that certain sheep in his flock were more adapted to the rocky terrain They were more sure footed than others, would graze faster and closer, and therefore could

produce more wool. He and other sheep raisers of the area naturally saved offspring of these *particular* sheep and not of the others, so in time there may have developed a sheep breed that *increased* wool production *in that particular environment.*

At the same time a sheep raiser in some fertile valley in England, where nutritious grass and root crops grow well, may have observed that certain of his rams and ewes consistently produced lambs that fattened and were ready for market quicker than lambs from others. They apparently were able to make better use of the feeds produced in this area, to produce meat and at the same time produce a good fleece. He naturally developed his flock by selecting replacements from his best ewes and rams and eventually he and his neighbors, or their ancestors, may have developed a breed that *increased* meat production under those particular conditions.

In brief, most breeds have developed from animals that were particularly well adapted to a specific environment, producing in that environment the kind of product desired.

The above examples have been repeated in some manner hundreds of times, among all livestock species, and in nearly every country on the globe. In England, almost every valley has a separate breed of sheep. In Germany there are five major breeds of cattle just for the lowlands—one mainly for the heavy soil area, one for the lighter soil, etc. There are seven major breeds of mountain cattle in Germany. In Norway, because of the great range in latitude and soil type, there are seven important breeds of cattle, and no one breed is normally found in more than half of the country.

It is certainly possible that two or more breeds may have been developed simultaneously for adaptation to and top production in the same kind of environment. This was certainly feasible in the seventeenth and eighteenth centuries, when most of the world's present breeds were being developed. With little or no communication, livestock raisers in one section of the country or world could have been totally unaware of developments occurring in other regions. This may explain similarities in production traits observed among two or more breeds today. A breed of dairy cattle, selected and developed for roughage utilization and maximum milk production in southern Sweden, for example, may have similar production traits and be adapted to the same kind of environment as a breed developed for the same traits in southern Chile.

There is a certain amount of pride associated with breed development. Those who have been responsible for development of a breed want the breed to be unique, at least in color markings and other obvious traits, as well as in production characteristics. This pride is passed on, through generations of breeders, and has persisted for centuries in most breeds.

In the first paragraph of this chapter a breed was defined as a group of animals with distinguishable characteristics. These distinguishable char-

acteristics—usually color markings, but also sometimes wool cover patterns, size, and shape—soon become an *effective* and *well-known* "trademark," though they may have little *economic* significance in terms of meat, milk, and/or wool production.

19.2 Chronology of Breed Development

Breed development may have begun soon after animals were first domesticated. Though time of domestication is not known for all species, reports indicate swine were domesticated in Eastern Asia about 2900 B.C. and in Europe about 1500 B.C. Cattle and sheep were domesticated in prehistoric times. The Bible contains many references to use of the various livestock species and hints that some attention had been paid to differences in producing ability among animals. Table 19-1 presents a sketchy chronology of the development of present breeds.

Several significant items are apparent in this table. The first is the early development of distinguishable breeds of cattle for milk production. This may have been influenced by the recognition of milk as a valuable human food efficiently produced from forage. Development of specific dairy breeds in the certain areas also may have been encouraged by local customs of cheese or butter making. Since milk was a highly perishable product that had to be produced in the immediate area, cows which were the best producers were easily identified. Local pride for high production and uniformity, and the proximity of the cattle raisers, may have allowed and encouraged exchange of breeding stock and development of a specific breed within the area.

The Holstein Friesian cattle are known to have originated in western Europe more than 2000 years ago, in the area now known as the Netherlands. Though the name Holstein was not attached to them until 1864, they were highly selected and relatively uniform in traits for many years before. The Brown Swiss, Jersey, Guernsey, and Ayrshire also developed within rather limited geographical areas. The Brown Swiss were developed in accord with the cheese making industry of Switzerland, the Jersey were especially well adapted for producing milk and butterfat on the Jersey Island's lime deficient soil. Guernsey milk produced excellent butter, a major product of the island of Guernsey which has an area of only about 24 square miles. The Ayrshire breed combined good milk production with economical beef production, desired by the livestock raisers in the low income area of southwestern Scotland where the breed developed.

Groups of animals became associated with the county, valley, or geographical area where they were selected or developed, and often became known by the name of that area. Most breeders who were involved in these breed development processes over a period of years or centuries were probably not aware that they were developing a breed as we know it today.

Table 19-1. A Chronology of Breed Development*

CATTLE: DAIRY	CATTLE: DUAL PURPOSE	CATTLE: BEEF	YEAR A.D.	SWINE	SHEEP
		Angus[1] - Scotland	1550		*about 1500 B. C.* - Angora goat Asia
about 100 B. C. - Holstein-Friesian Europe					
		Shorthorn England	1575		
about 1100 A. D. Guernsey - Guernsey Island					about 1000 A. D. - Merino - Spain
			1600		
			1625		
			1650		
			1675		
			1700	Berkshire England	
			1725		
Jersey - Jersey Island					
		Hereford England	1750		Lincoln - England Leicester - England
			1775		Rambouillet France Southdown - England Cheviot - England and Scotland
• Holstein[2] Ayrshire - Scotland		• Shorthorn			
Brown Swiss - Switzerland			1800	Chester White - Pennsylvania Yorkshire Tamworth England Hampshire U S.	• Merino • Southdown
• Ayrshire		• Hereford	1825	• Berkshire	Romney - England • Cheviot Hampshire Dorset England
• Guernsey	Red Poll - England			Poland China Ohio	• Rambouillet Hampshire *Cotswold Oxford - England*
• Jersey		• Brahma	1850		• Angora goat, Oxford Shropshire, Suffolk - England • Shropshire
• Brown Swiss		• Angus		Duroc - U S.	
			1875	• Tamworth • Yorkshire Landrace Denmark	Corriedale - New Zealand • Dorset Suffolk
			1900	*Spotted Poland China* - Indiana	• *Romney* Karakul Columbia - U S.
		Santa Gertrudis - U. S.	1925	Hereford - Missouri	Targhee - U S. Romeldale, *Panama* - U. S. Debouillet, Montadale - U. S.
		Beefmaster - U S. *Charolaise* Brangus - U S. Charbray - U. S.	1950	• Landrace Minn. 1 2 Mont 1 Md 1 Palouse - U S. American Landrace - U. S.	
			1975		
			2000		

[1] Breed names not preceded by a black dot are placed to show the approximate time the breed attained identity as a breed (though the name may have been different), according to information available, and the area where it was developed or became identified as a breed.

[2] Breed names that are preceded by a black dot are placed to show the approximate time animals of the breed were first imported into the United States, according to information available.

*Information gathered from many sources, including, with permission, H. M. Briggs, *Modern Breeds of Livestock*, second edition, The Macmillan Company, New York, 1958.

In contrast to early development of our presently popular dairy breeds, beef breeds, and some of the sheep breeds, many of today's swine breeds are of recent differentiation. This does not mean that hog raisers centuries earlier did not have breeds. History indicates they did. It probably does mean that the higher prolificness of swine has allowed swine raisers to develop new breeds more rapidly (Section 17.1), to more adequately fit the environmental conditions. As the United States was settled, breeding animals were brought from Europe and used as foundation stock for breeds adapted specifically to this country. At the same time, European breeders used some of the same, or other breeding stock, to develop new breeds for their needs.

It is apparent in Table 19.1 that many of the breeds we now use were developed in Europe, especially in England or Scotland. Certainly the livestock raisers in these areas were industrious, observing, and good selectors of breeding stock, but this does not mean that livestock raisers in other areas were latent in breed development.

Remember that most of the early American settlers *came* from western Europe and that much of our trade and communication has been with this area because of closeness, ancestry, similar habits and customs, etc. Recognize, too, that the climate and topography of much of the United States is similar to that of western Europe. Livestock that was well adapted to conditions in western Europe was likely to be raised successfully in the United States.

Other countries of the world have been very active in breed formation and have successfully developed breeds of livestock specially adapted to their conditions. Only in recent years, however, have many of these other countries been tapped as sources of breeding stock for livestock improvement in the United States.

19.3 Variation Within Breeds

Though breeds each have certain distinguishable characteristics, there is also much variation *within* each breed, especially in economically important production characteristics. Some of the variation observed may be due to environmental causes, since breeds are raised under widely varied conditions, but much of the variation is known to be genetic. It is not uncommon for beef calves within one herd to vary 75 to 100 pounds in weight at a standard weaning time. Dairy cows, within a breed and herd, may vary considerably in butterfat percentage, and more in milk production. Similar variation exists within breeds of other species.

Most breeders have extreme loyalty to their breed and considerable ire is raised when someone ranks a breed lower in a particular trait than another breed. Therefore, when a question is asked, "Which is the best breed for milk production, prolificness, etc.?" an educator is often thank-

ful for the variation and simply says, "There is more variation within the breed than among the averages of breeds," and everybody stays happy, but totally uninformed.

That genetic variation exists simply indicates that the breeds are not genetically "pure." Though essentially all animals in the breed may carry the same genes for color markings or other noticeable traits, there is considerable range in genes present which influence other traits. As long as cross fertilization of male and females are required for conception in livestock, breeds or lines of animals totally pure in gene composition will be impossible to achieve, except by pure chance. Even if such occurred by chance and a male and female of identical gene make up were mated, the breeder probably wouldn't realize it.

It is possible that some of the variation in production traits which exists today within breeds has been allowed by selecting, in some cases, on the basis of color markings, unimportant phenotypic traits, and fads, rather than strictly on the basis of economic merit. This may have allowed not only increased *variation* in production traits, but also *lower* average productive merit.

Remember, of course, that some genetic variation is essential in order to make progress by selection (Section 14.7).

19.4 Cattle Breeds

For purposes of adaptation to geographical areas and products desired, cattle breeds have differentiated into three general groups—dairy, dual-purpose, and beef. The most common breeds in the United States are listed below.

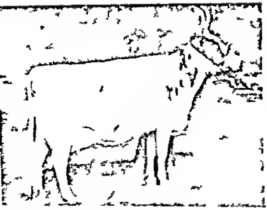
Dairy		*Dual-Purpose*	*Beef*	
Ayrshire	Holstein	Milking Shorthorn	Angus	Charolaise
Brown Swiss	Jersey	Red Poll	Brahman	Hereford
Guernsey			Brangus	Santa Gertrudis
			Charbray	Shorthorn

The classification given is not completely descriptive. An estimated 40 per cent of the beef consumed in the United States, for example, comes from cattle that are primarily dairy breeding. Similar breeds in some other countries are the *major* source of beef. The Ayrshire was considered a dual-purpose animal during much of its early development, and the Brown Swiss is considered such by some breeders today. Though the Milking Shorthorn is a distinct part of the Shorthorn breed, some excellent dairy herds of Milking Shorthorns have been developed that could hardly be called dual-purpose.

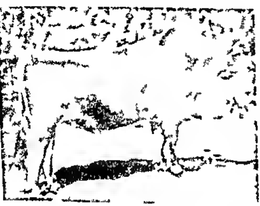
The amount of milk consumed by Americans that comes from cows with considerable beef breeding is not known, but it may well be substantial.

Figure 19 1 Some of the major breeds of dairy and dual purpose cattle raised in the United States (Courtesy of respective breed associations)

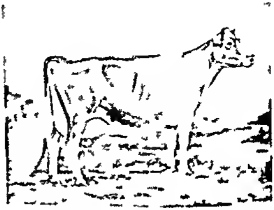
Figure 19 2 (Opposite Page) Some of the major breeds of beef cattle raised in the United States (Courtesy of respective breed associations)



Ayrshire cow



Brown Swiss bull



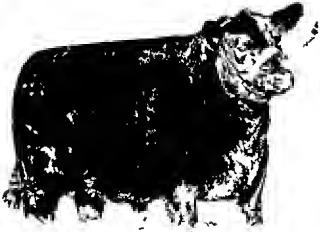
Guernsey cow

Holstein cow

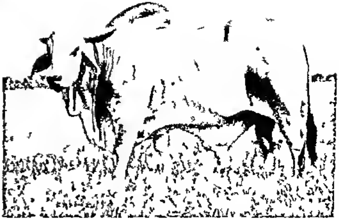
Jersey cow

Milking Shorthorn cow

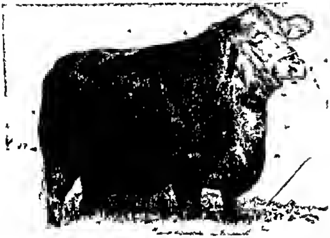
Red Poll cow



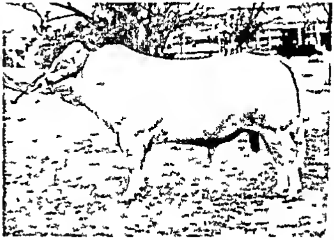
Angus steer



Brahman bull



Brangus cow



Charbray bull

Charolaise bull

Hereford bull

Santa Gertrudis cow

Shorthorn bull

In modern livestock raising one must pay less attention to the "textbook classification" of livestock and more attention to the specific traits—rate of gain, pounds of milk produced, percentage of lean in the carcass—of the breed or of animals within the breed Unfortunately space does not permit thorough coverage of these traits here

19 5 Swine Breeds

Swine are raised to produce lean high quality pork All breeds have this common purpose, though there are differences in the degree to which the goal is achieved At one time breeds of hogs grown in this country were classed as ' lard type' and ' bacon type " Though the individual breeds continue, this classification has all but disappeared and hog raisers, regardless of breed or breeds used are all aiming for the same kind of product

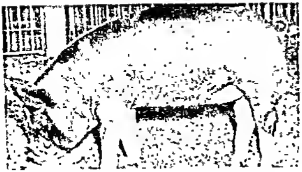
Since crossbreeding is almost universal in commercial hog production, breeds may be selected and used for crossing that would not be raised as a pure breed for commercial production When the Landrace breed was first imported into this country, for example, boards of that breed were generally more valuable for crossing with sows of other breeds (usually lard breeds of English origin) than they were for mating with Landrace sows At that time the Landrace were highly inbred difficult to raise, and not efficient meat producers on the average American farm But when crossed with another breed the offspring were vigorous and fast gaining, and the carcasses produced were leaner than those produced normally by the lard breed

Common breeds of hogs raised in this country are listed below

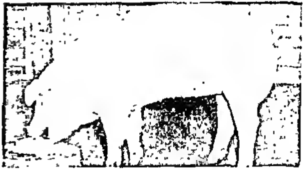
Berkshire	Hampshire	Spotted
Chester White	Landraee	Tamworth
Duroc	Poland China	Yorkshire

There are other breeds, developed by state agricultural experiment stations and the USDA in recent years—Minnesota Nos 1, 2, and 3, Montana No 1 Maryland No 1, Beltsville Nos 1 and 2, and the Palouse The San Pierre and Hereford are also recognized as breeds Many of these more recently developed breeds are classed as inbreds because they were developed by rather intense inbreeding *after* being started by the crossing of two or more breeds The more established breeds were started similarly, but developed over a longer span of time and with much less intensive inbreeding

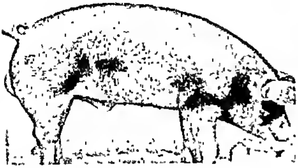
Though space does not allow consideration here, more is known about the productive ment of swine breeds and individuals or families within the breeds than is true for sheep or beef cattle Consumer demand for high quality pork high feed costs, and narrow profit margins have encouraged development of swine testing stations and on the farm testing programs which identify potential breeding animals with top genetic merit Such test



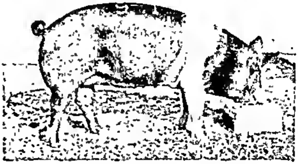
Berkshire gilt



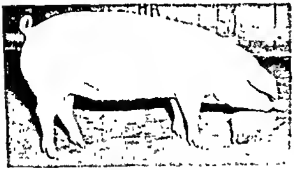
Chester White gilt



Duroc boar



Hampshire gilt



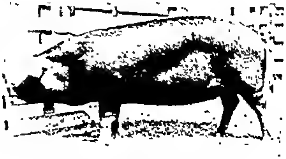
Landrace gilt

Poland China barrow

Spotted boar

Tamworth boar (mature)

Yorkshire gilt



Minnesota No. *1* boar

Figure 19-3. Some of the major breeds of hogs raised in the United States. (Courtesy of respective breed associations)

ing programs have allowed accumulation of much factual data on breed performance

19.6 Sheep Breeds

These are the major breeds of sheep raised in the United States

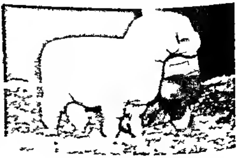
Fine wool breeds	*Meat breeds (medium wool)*	
Merino	Cheviot	Hampshire
Rambouillet	Columbia	Oxford
	Corriedale	Shropshire
	Dorset	Southdown
	Suffolk	

As in dairy cattle this 'textbook classification' may be misinterpreted. The Merino and Rambouillet were developed for high production of fine high quality wool, but much lamb and mutton consumed certainly comes from animals that carry Merino or Rambouillet breeding. And with the meat breeds, wool represents a sizeable proportion of total income from the flock.

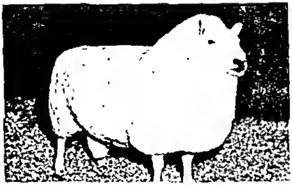
Meat breeds developed more recently in this country include Targhee, Panama, Romeldale, Debouillet, and Montadale. The opinion is sometimes expressed that there are more breeds of sheep raised in the United States than necessary. Nevertheless, each breed has enthusiastic supporters and breeders. Also, certain large sheep raisers have, in effect, developed their own 'breed' or family of sheep specially adapted to their area and needs.

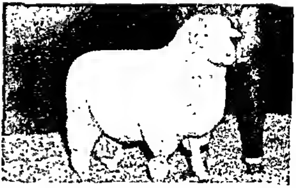
Relative fineness of wool from the various breeds is indicated in Table 27.1, and indicates considerable range. There is much range in other production characteristics too. Southdown and Shropshire sheep, for example, are relatively small and compact. Though they produce excellent carcasses, other breeds such as the Hampshire, Suffolk, and Columbia are more adapted to commercial lamb production because of larger size and more rapid gains.

Merino ram

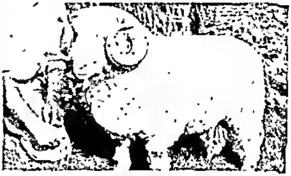


Rambouillet ewe


Cheviot ram

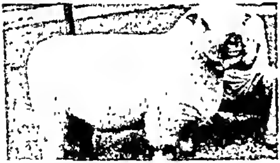

Columbia ram


Corriedale ewe


Dorset ram


Hampshire ewe


Oxford ram


Shropshire ram


Southdown ewe

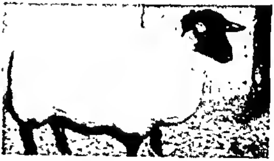

Suffolk ewe

Figure 19-4. Some of the major breeds of sheep raised in the United States. (Courtesy of respective breed organizations and *The Sheep Breeder and Sheepman*)

There are several breeds of long wool sheep which are also classed in the meat group because their meat production is considered most important and their wool is relatively low in quality. These breeds, including the Leicester, Lincoln, Cotswold, and Romney, are not popular in this country partly because their low quality wool is not protected from foreign competition by import tariff.

19.7 The Future of Livestock Breeds

It is recognized that development of presently popular breeds, especially those developed in former centuries, was slow. Most was done without knowledge of the science of genetics, without as many techniques for quantitative appraisal of production traits as we now have, without fast communication, and without easy shipment of breeding stock among counties, states, countries, or continents. Recently developed breeds have attained the breed designation faster because of these advantages.

Where do we go from here in breed development? The present term, breed, may lose some of its significance and be partially replaced by the terms strain and line in future livestock improvement, especially with meat animals. Such is already the case in poultry production.

There is evidence that livestock producers are more concerned with production characteristics and less concerned with color markings which have long served as breed trade-marks. Breeds will, no doubt, continue as distinguishable groups within species. But within these breeds, there will be further development of individual lines or strains, selected for specific traits and/or for crossbreeding purposes.

The proportion of animals that are registered purebreds will probably remain small, and performance records of animals may become as significant in livestock selection as breed registration.

20

LIVESTOCK MARKETS

Markets are the link between livestock producer and processor, as well as a link between producers A market is the place where buyer and seller meet The buyer may be looking for livestock for slaughter or feeding Little breeding or dairy stock is sold through typical markets, most is sold by private treaty or at special auctions

There are many kinds of markets *Terminal markets* such as those in Omaha, Ft Worth, Denver, and Lancaster, Pennsylvania, handle large volumes of livestock *Auctions* are increasing in number and relative importance *Dealers* play a tremendous role in livestock marketing, especially in movement of feeder livestock and some slaughter hogs Various types of *cooperative marketing associations* also exist Most of these are organized by groups of producers or by farm organizations and represent the producer in dealings with prospective buyers

Buying stations operate in much of the Midwest, accumulating fed cattle, lambs, and hogs for certain meat packers The latter might be termed "direct" marketing since the buying stations are usually owned by packers and manned by their employees Other slaughter livestock may be sold direct to the packer at his plant Many *feeder* cattle, lambs, and pigs are also sold direct, with no middleman used to negotiate the sale

Direct marketing is interpreted here as marketing *without* the services of a third party negotiating the sale between buyer and seller At terminal markets, in auctions, and with dealers there is a third party, who takes title to the livestock temporarily or who is paid a commission for negotiating a sale or purchase This is emphasized here because some writings list all forms of marketing other than terminal markets as direct marketing

Estimated percentages of livestock sold through different market channels in 1955 are given in Figure 20 1

20 1 Terminal Markets

Terminal markets are also called public stockyards or central public markets They are livestock trading centers with complete facilities for receiving caring for, handling and selling livestock on a private treaty

MARKETING CHANNELS FOR LIVESTOCK

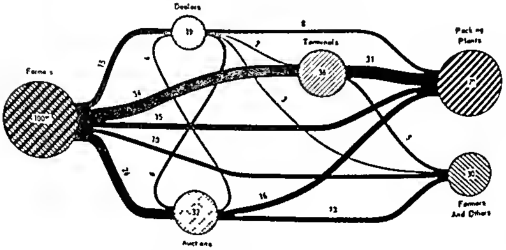


Figure 20-1. Marketing channels for livestock in 1955 Most livestock sold to "farmers and others" would be feeder cattle, lambs, and pigs

basis All buyers and sellers are privileged to use the facilities. Essentially all livestock sold here is sold by commission firms, who act as *agent* for the seller.

The 64 terminal markets in the United States vary greatly in size. The 10 largest handle over half the livestock sold through this type market. Though several markets in range areas handle many feeder cattle and lambs, most of the larger terminal markets are in or near the Corn Belt (Figure 20-2).

Several agencies at a terminal market assume rather specific functions. These usually include the stockyards company, commission firms, livestock exchange, dealers and traders, traders exchange, and a market news service. Other agencies, such as banks and insurance and transportation companies make a large terminal market almost a self-contained city.

The *stockyards company* provides the facilities—pens, alleys, scales, unloading docks, feed, water, and sorting equipment. Cattle pens are usually in the open, sheep and hog facilities usually sheltered The stockyards company usually provides the central office building at the market In effect, they operate a "livestock hotel" Their employees help unload or load livestock, move the animals to and from pens and scales, distribute feed, and operate the scales at a market.

Commission companies act as agent for the seller in most cases For this service they receive a set commission per head, just as a real estate

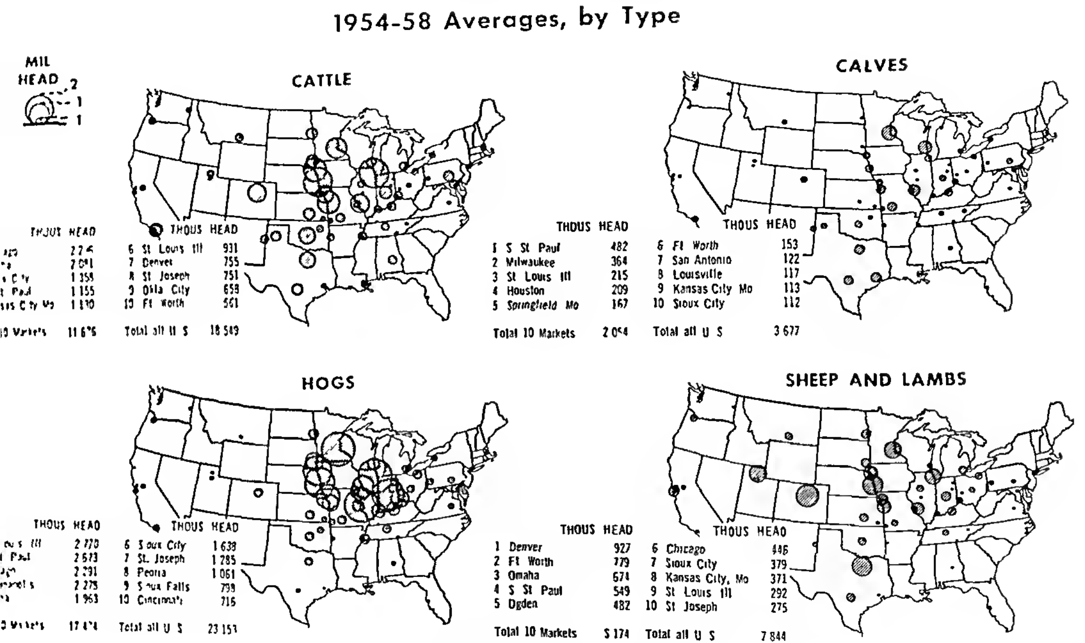


Figure 20-2. Relative salable receipts of livestock at terminal markets in the U S, 1954 to 1958.

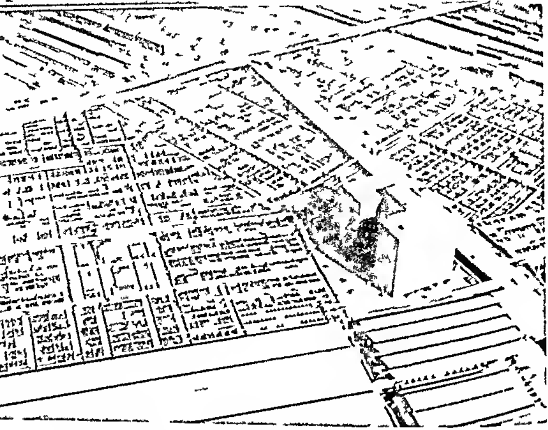


Figure 20 3 The term nal livestock market at Omaha The sheep barn is at lower left the hog barn and unloading docks at lower right (Omaha Livestock Exchange)

salesman receives a commission for selling property Commission companies operate within certain areas on the market The stockyards company may assign certain cattle sheep and hog pens to each commission company according to their normal volume of business As many as 40 different commission companies operate on some markets

As agent for the seller the men of the commission company sort and pen the livestock to make them appear most attractive to buyers and strive to obtain highest possible prices Commission rates are usually *per head* not a percentage of sale price and are rather tightly controlled by government regulations The commission company assumes responsibility for obtaining payment for livestock sold deducting commission fees yardage fees for the stockyards company insurance and other expenses then forwarding the remainder to the seller or his bank The seller pays a yardage fee for use of the facilities and feed for the livestock This is the major source of income to the stockyards company commission companies usually do not pay rent on the pens in which they operate

Most terminal markets have a *Livestock Exchange* an organization of commission companies who operate on the market Like the Chamber of Commerce in a typical town the Livestock Exchange promotes and publicizes the market encourages fair dealing settles disputes which might arise and encourages all member commission companies to charge standard commission rates and provide good service Most livestock exchanges employ an executive secretary to handle much of this work

Dealers or *traders* operate on many markets, especially dealing in feeder cattle. These men rent pens from the stockyards company, buy and take title to livestock, then sort and group for resale hoping to make a profit. Dealers are numerous on many western markets and on those along the Missouri River. At most of these markets a certain group of the cattle pens is designated as the "Dealer and Trader Division." Many such markets have a Traders Exchange whose functions parallel those of the Livestock Exchange.

In recent years many of the large markets have formed a *Market Foundation,* primarily designed to promote and develop the market in any way possible. All who have a stake in the continued operation and success of the market—packers, stockyards company, livestock exchange, traders exchange, order buyers, transportation companies, banks, and other businesses in the particular city—contribute to the Foundation and its operation.

A variety of livestock buyers operate on a terminal market. Since several packers are usually adjacent to the market, packer buyers continually purchase slaughter cattle, hogs, and sheep of various weights and grades. They may be competing with buyers for other processors, or *order buyers,* each of whom might buy for several distant packers.

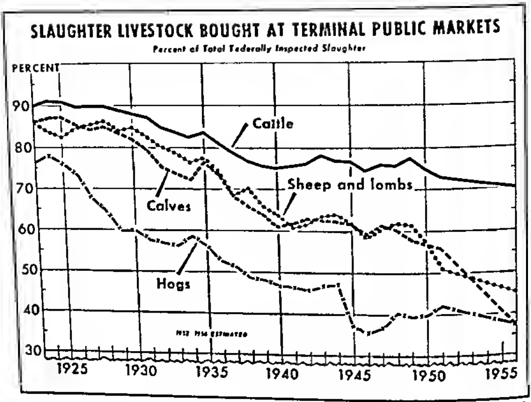
Farmers and feeders may be on hand to purchase feeder cattle or lambs, though most buy through feeder order buyers. Few feeder pigs are sold at terminal markets.

Terminal livestock markets have certain unique characteristics. A nod of the head or a spoken word takes the place of a written contract on transactions mounting into millions of dollars daily. All livestock is sold on a live basis. The buyer "pits" his judgment of dressing percentage and carcass quality against that of the seller. Livestock markets include some of the world's most adept salesmen and buyers. Payment is made on the basis of weights taken soon after a sale is made.

The proportion of livestock sold through terminal markets has declined in recent years (Figure 20-4). This may be due to such factors as (1) establishment of more packing plants in producer areas and closing of some plants in cities where terminal markets are located, (2) increased selling of slaughter stock on a "grade" and/or "yield" basis, and (3) fast growth of auction markets.

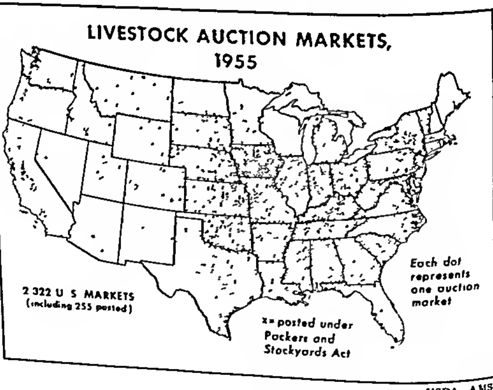
20.2 Auctions

Livestock auctions, also referred to as sale barns, community sales, or community auctions, are trading centers where animals are sold by public bidding to the buyer who offers the highest price per cwt. (100 lbs.) or per head (see also Figure 2-6). Increases in livestock auctions have been



USDA, AMS

Figure 20-4. Percentage of slaughter livestock sold at terminal markets, 1923-1956



USDA, AMS

Figure 20-5. Distribution of livestock auction markets

phenomenal. The number in this country rose from about 200 in 1930 to over 2300 in 1960 (see also Figure 20-5).

About 75 per cent as many cattle, yearlings and older, are sold in auctions as in the terminal markets, and about twice as many calves go through autions.[1] Auctions have flourished in feeder producing areas such as in Texas and the Sand Hills of Nebraska, perhaps because of the heavy seasonal movement of feeders. Many auctions are also located in the intensive feeding areas.

Some estimates[2] indicate that 50 per cent or more of each species—hogs, cattle, and sheep—sold through auctions are sold for slaughter (see also Figure 20-1). This may be surprising to those who have thought of auctions primarily as markets for feeders and for interfarm sales.

Auctions differ from terminal markets in that all prospective buyers view and bid on the animals at the same time, while they are in the auction ring. At terminal markets commission salesmen deal with each buyer individually and usually accept or reject bids before that buyer leaves the alley and another buyer comes to bid.

Sales in an auction are also made with the nod of the head or a spoken word. Traditionally, the auctioneer starts livestock at a reasonable price, asks for and receives successively higher bids, and sells the animals in a few minutes to the highest bidder. Commission rates usually include all yardage fees and are near 3 per cent on the first \$500, 2.5 per cent on the second \$500, and 1.5 per cent on that portion of a sale over \$1000.

In some countries a different auction system operates. As a group of animals enters the ring, an excessively high price is registered on an electric board. The price gradually decreases by small increments until a buyer yells, nods, or pushes a special button to indicate purchase. One who wants to buy the animals will wait until he is sure the price is as *low* as it will go, but before a competitor buys.

20.3 Dealers

Many livestock dealers own or rent specific "yards" where they actively buy and sell feeders or slaughter livestock. A large number of independent dealers operate buying stations for fed hogs, cattle, and lambs in the Corn Belt. Animals purchased are then sold to close or distant packers, the dealer hoping to make a profit on price per cwt. or on weight.

Many dealers in or adjacent to heavy grain producing areas buy large numbers of feeder lambs, calves, or pigs for resale. In some cases feeder cattle may be purchased *for* the dealer in the range area by an order buyer. The same may often be true for lambs and pigs.

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[1] AMS, USDA, *Marketing Res. Report 216*.
[2] Gerald Engleman, Livestock Section, MRD, AMS, USDA, "The American Livestock Auction Market—Its History, Importance, and Problems," 1955.

Dealers in many parts of the country handle dairy herd replacements, breeding animals, and a variety of other livestock

Most dealers also have some other business, such as an auction or a truck line Quite a few operate feed lots Since dealers often buy odd groups to hold for an expected price increase, feed lots or a farm to handle these animals is often essential

Though many dealers operate at a specific establishment and do a relatively routine business buying and selling feeders or slaughter animals with steady clients, some are much more speculative Most dealers on terminal markets are highly speculative They buy odd lots of livestock at the market, at country auctions, or from other dealers then sort and regroup for later sale at the same or other markets Other names for such dealers are "scalpers," "traders," and "truck buyers"

Dealers often supply an appreciated outlet for livestock at certain auctions and terminal markets Naturally they hope to make a profit on price increases, but often make their profit on amount of "fill" the animals might carry when weighed

20 4 Order Buyers

The term order buyer was mentioned in Section 20 1 as one who buys fed cattle, lambs, or hogs at a terminal market for some distant packer He usually receives a standard commission rate for this service, and handles all sorting, loading, and insuring of purchased animals for his client

An order buyer may also buy feeders for the farmer at a terminal market, at an auction, on a ranch in Colorado, or on a farm in Wisconsin. Order buyers are not restricted in place of operation Packers and feeders are often willing to pay for the services of an order buyer because (1) the buyer is where the stock is available and (2) they depend on his judgment and ability to buy what they want at the lowest possible prices

Though terminal markets, auctions, dealers, and order buyers are separated here for discussion purposes, there is actually much overlap Many who own or manage auctions also act as dealers or order buyers So do certain commission salesmen who work primarily on terminal markets Depending on the size of the market involved, many such arrangements come under scrutiny of federal regulations (Section 20 8)

20.5 Direct Marketing

Direct marketing implies no middleman Transactions are made directly between the buyer and seller Direct marketing of both feeders and slaughter animals has increased in recent years

An accurate estimate of the percentage or number of feeder cattle, lambs, or pigs sold direct is not available Since such animals do not regu

larly pass through any certain points, it is impossible to make an accurate count.

As livestock feeders and ranchers have become more specialized and larger and as communication and transportation have markedly improved, it has become easier for buyer and seller to negotiate directly. Ranchers are more aware of current prices and true value of their feeder calves, lambs, or yearlings. Feed lot operators, since they buy in larger groups, have trained themselves to better appraise feeders and keep abreast of price trends.

Certain associations of growers and feeders have promoted this trend toward increased direct marketing. The Sand Hills Cattle Association, for example, sends direct mail advertising to Midwest feeders, listing age, breed, and sex of feeders available on certain ranches. Some county cattle feeder associations in Iowa and Illinois have organized trips into feeder producing areas to acquaint feeders with ranching practices and for feeders to look at available cattle. Rancher groups have reciprocated by visiting feed lot areas.

The increase in direct marketing of slaughter animals has been more measurable because of the ease of counting receipts at packing plants. Figure 20-1 indicated recent percentages sold directly to packers (including packer-owned buying stations) in 1955. Proportions of slaughter animals sold directly to packers are apparently higher in intensive feeding areas for all species, but are also high in the Pacific and Mountain areas for slaughter cattle and lambs.[3] Compare percentages sold direct in Iowa (Table 20-1) with averages for the United States (Figure 20-1).

Table 20-1. Percentage of Livestock Sold by Iowa Farmers at Various Types of Markets, 1954*

Type of market	Barrows and gilts	Sows	Beef steers	Beef heifers	Vealers
Terminal markets	13.8	17.5	57.3	55.8	—
Direct to packer	58.4	45.8	24.8	16.8	12.6
Auction	0.8	3.5	10.0	11.2	77.5
Dealer	25.3	25.7	3.4	5.5	9.9
Cooperative	1.4	0.6	—	—	—
Another farmer	—	6.4	3.7	10.3	—
Other	0.3	0.5	0.8	0.4	—

*Sam M. Thompson and Wilbur R. Maki, *Iowa Farm Science* 14-2 7, 1959. Presumably the livestock was sold for slaughter except for a few of the sows, heifers, and vealers.

Increased direct marketing of slaughter livestock has been due to several factors: (1) Decentralization of packing plants from large cities to producing areas; (2) Replacement of rail movement by trucks; (3) Establishment of packer buying stations in many communities where much livestock

[3] AMS, USDA, *Marketing Res Report 216.*

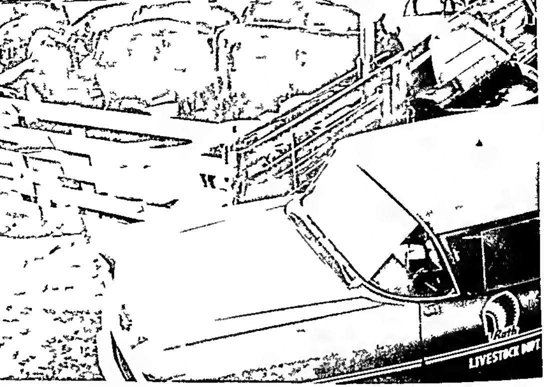


Figure 20-6 A packer buyer at the feedlot bids on fat cattle which will be delivered directly to the packing plant. This is an example of direct marketing (The Rath Packing Company)

is raised, (4) Better communications—radio and telephone—which, combined with closeness of plants and buying stations have made it possible for the seller to deal directly with the buyer [He likes to *know the price* before the animals leave the farm (Figure 20 6)], and (5) Opportunity to sell on the basis of grade ' and/or yield '

The decentralization of packing plants and the establishment of the many buying stations have made direct selling of fed cattle, lambs, and hogs more *convenient* A number of surveys have shown that decisions on selection of a market are based as often on convenience or location as they are on probable prices Transportation costs are lower because of shorter distances There is no yardage fee or commission charge to pay Though direct marketing may not necessarily mean more *net return* to the seller, elimination or reduction of these *obvious* marketing costs make it more attractive to him

Since the feeder may obtain a bid by phone or by a packer buyer visiting the farm, the price per cwt can be established before the animals leave the farm This makes the feeder feel more *secure* than when he hauls his animals to a distant market or auction

At a terminal market or auction he often feels at the mercy of buyers There may be a few buyers and prices might go down before his livestock is sold Even if he declines all bids, he usually has fixed charges to pay, transportation costs both ways and some weight loss on the animal Of course, there may be *many* buyers competing for his stock, and price *might go up*

20.6 *Marketing Costs*

A number of expenses are incurred in livestock marketing, varying according to type of market, distance livestock are moved, and other factors These may include commission charges, yardage fees, insurance in transit and at the market, transportation, and perhaps shrink of or injury to the livestock Deductions from sale price may also be made at the market for use in meat promotion (Section 25 8) This is especially true for slaughter livestock

Commission rates and yardage normally charged at terminal markets are relatively small—each under 1 per cent of the value of the animals sold This compares with a normal commission charge of about 2 per cent when securities are bought or sold, or about 5 per cent often charged in real estate transactions Since fees are usually on a per head basis, it costs *more* to sell a poor quality animal on the market, *in relation to its value*

Commission charges for auctions were mentioned previously (Section 20 2) and usually *include* all yardage fees and insurance since there is only one party involved in providing facilities and the service of selling

Other charges, such as insurance and transportation, vary so greatly that a thorough discussion is not worthwhile Where trains are used, though, and livestock are shipped to a terminal market where they will be sold and perhaps shipped further, it sometimes pays to take advantage of "through billing" rates Charges are calculated on the basis of one long trip, from origin to final destination, rather than on the basis of two short trips There is considerable governmental control of livestock transportation rates, especially with trains

An advantage often listed for direct marketing is that there is no marketing cost There is, however, still transportation and transit insurance And when packer owned buying stations are used, there is some cost in maintaining them Since there is no yardage fee, this cost must eventually be reflected in livestock prices

Weight loss—shrink—may be a large expense in livestock marketing, depending on *when the shrink occurs* and *when the animals are weighed* to establish sale weight If weight loss results only from loss of gastrointestinal contents or urine, then the shrink is only superficial and there is no real loss of tissue If this is the case and slaughter animals are sold on a carcass weight basis, there is no financial loss to the seller If, however, animals are sold on a live weight basis and the price is already determined, there definitely is financial loss to the seller and the buyer profits

Seldom does much tissue shrink occur in normal movement and marketing of slaughter animals Extremely hot weather, long hauls, and poor watering facilities at the market would tend to allow tissue shrinkage Sugar

in the ration just before shipment has been used to reduce tissue shrinkage Presumably the sugar molecules are readily absorbed into muscle cells and help retain more water there

Most of the shrink occurs the first few miles of a trip (Table 20-2) This means that almost as much shrink may occur when livestock are marketed at a nearby market as when shipped to a more distant market

Table 20 2 Percentage of Weight Loss in 60 Slaughter Cattle During a 200 Mile Truck Haul*

Weight Classes	Number of head in each class	Average weight	Miles traveled between weighings: 0 25	25 50	50 100	100 200	Total percentage
Group Average	60	1122	1 8	0 7	0 8	0 6	3 9
Under 1000 lbs	11	954	1 5	0 7	0 9	0 8	3 9
1000 1099 lbs	10	1056	2 1	0 9	0 8	0 3	4 1
1100 1199 lbs	24	1139	1 8	0 8	0 8	0 7	4 1
Over 1200 lbs	15	1263	1 9	0 5	0 7	0 5	3 6

*Chicago Union Stock Yard and Transit Co

It is apparent that the time and conditions under which animals are weighed are important to determine who if anybody, loses because of transportation shrink Though shrink may be less when slaughter animals are sold direct to a local packer, animals are usually weighed *at arrival* without having access to feed or water Because of greater distance on the average to terminal markets shrink may be more, but animals *do have access to feed and water* before they are sold and the pay weight established

Tissue shrinkage is more likely to occur in movement of feeder cattle and lambs since longer distances are often involved Unless animals are in poor condition because of the shipment stress, such shrink might be quickly made up once the animals arrive and are given ample feed and water Tranquilizers and other treatments have been used in an attempt to lower transit shrinkage Such would have net benefit *only* if tissue shrink were serious and could be prevented

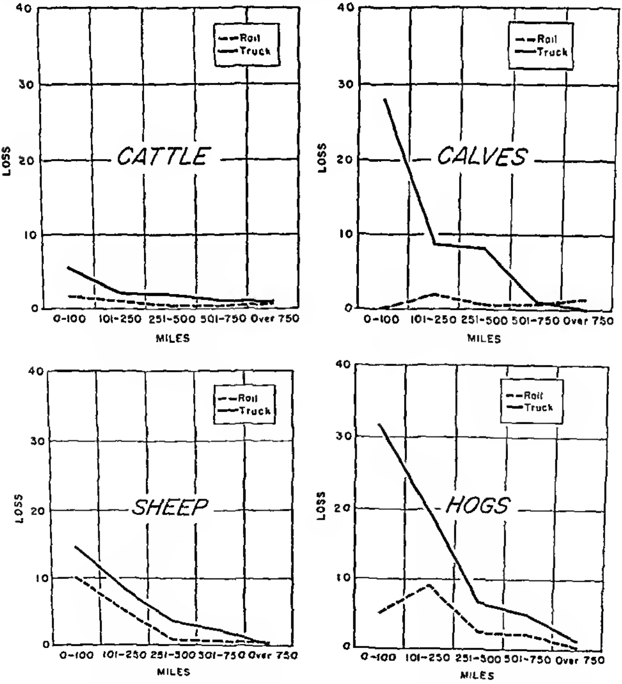
20 7 Moving Stock to Market

Most livestock goes to market in trucks About 85 per cent of livestock arriving at terminal markets in 1959 came by truck Trucks are used almost exclusively for distances under 200 miles and are being used increasingly for longer hauls Triple-deck trucks, for example, haul thousands of lambs each year from Montana to Midwest feed lots Slaughter hogs purchased at Missouri River terminal markets by order buyers are shipped to packers on the West Coast in triple-deck air-conditioned trucks Continued development of interstate highways will further promote use of trucks

Trains are used only for relatively long hauls, especially in the fall when masses of feeder cattle and lambs are moving long distances to markets and feeding areas.

Because trucks are used relatively more for short hauls and trains for shipping long distances, numerous surveys indicate injury to livestock is greater in trucks on a per mile basis (Figure 20-7). This would be expected, since there are more starts and stops, in relation to distance traveled, on short trips. Trucks are more bothered by traffic congestion, stop signs, etc., and perhaps there are relatively more inexperienced drivers.

Figure 20-7. Dead and cripple loss (4 cripples = 1 death) of cattle, calves, sheep, and hogs per 10,000 head per million miles traveled. (Farmer Coop. Service, USDA Marketing Res. Report 247)



Recent developments including "through" highways, special truck routes in cities where markets are located, and much emphasis on driver education to prevent crippling and bruising of stock, have greatly decreased losses in truck transportation.

Most transportation losses—bruising, crippling, and death—are the fault of a *person* one who has probably never seen a bruised loin on a beef carcass, a ham with pitchfork wounds, or a blood clot in the middle of a veal round, caused by a broken leg and ruptured blood vessels (see also Figure 23-7). Overcrowding causes bruising, especially of thin cows and steers which lack the protective layer of fat. Mixing species or different weight groups in a railroad car or truck is another common cause. Extremely hot, humid weather is a main cause of death in hogs and sheep. There are other causes of death, crippling, and bruises, *common sense* can avoid most.

20.8 Regulatory Agencies

The Packers and Stockyards Act, enacted in 1921 and amended several times since, provides for governmental scrutiny of the operation of all livestock markets 20,000 square feet in size or larger and all meat packers where products handled are normally shipped between states. The act therefore covers about 64 terminal markets, many auctions, and most large meat processors. Markets and meat processors who operate completely within state boundaries are subject to the laws of that state.

The act, administered and enforced by the USDA, provides that all market transactions be completely honest, and that there be no unfair competition, monopoly, price controlling, or restraint of trade. Since all such markets are considered *public markets,* the "public" is to be protected. Records of all transactions must be made in detail and must be available for routine inspection. Packers are prohibited from giving any undue or unreasonable preference or advantage to any person or any locality.

Enforcement offices are maintained at major markets to provide routine checking of operations and to receive complaints of alleged infractions. A recent example involved apparent discrimination at certain markets against farmers who wanted to bid on feeder cattle available there. Allegedly, commission salesmen allowed dealers and order buyers (who are on the market regularly) to draw for turns at seeing and bidding on the cattle, feeders and farmers were ignored. After investigation, the USDA issued an order to 'cease and desist' such procedures.

Scales must be accurate, checked routinely by state or federal agencies, and operated by bonded men. Those guilty of scale manipulations and causing false weights are subject to provisions of the Packers and Stockyards Act, including heavy fines and imprisonment.

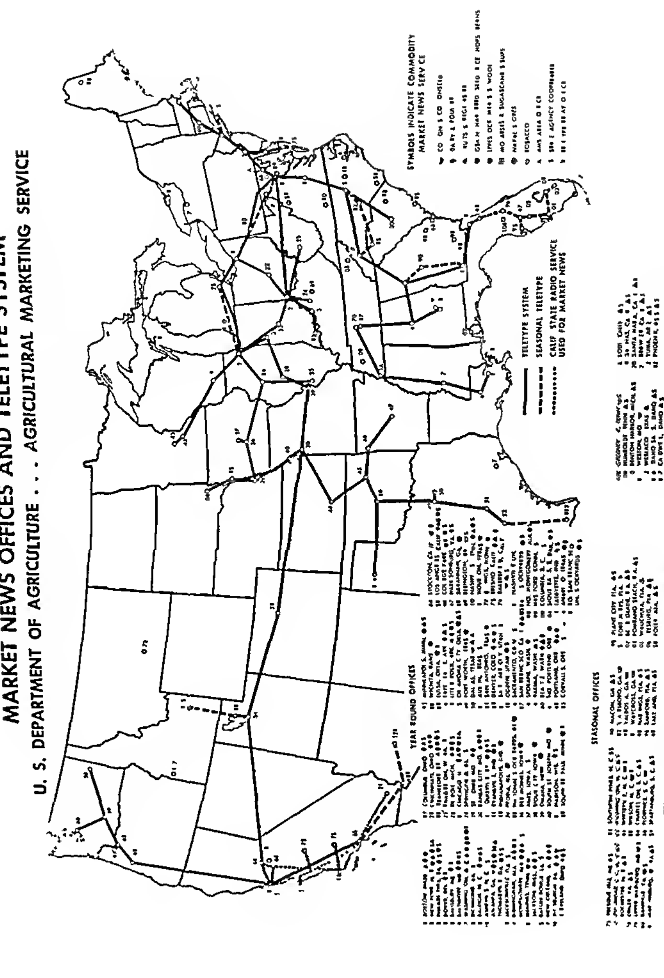


Figure 20-8. The leased wire network of the USDA, linking all major markets and marketing

20.9 Market News

Though there are many sources of livestock market news information—from packers, market foundations, dealers, commission companies, etc.,—the market news service which supplies the most complete information is provided by the USDA. Offices at all major markets, and in areas where buying stations and direct marketing are common, compile unbiased information throughout the day and disperse it to all points through a leased wire service (Figure 20-8).

Early each market day, before the market opens and trading begins, men of the Market News Branch, USDA, estimate the numbers of each class of livestock at the market. This information is put on wire, by teletype, and received simultaneously at all other markets (Figure 20-9) and by major news services. After the market opens and prices are established, this information is gathered and dispersed.

Figure 20-9. "What's the market?" Shippers and others at the Omaha market check livestock receipts and opening trade trends in the Exchange Building lobby. At the same time, market reporters from the USDA, market foundation, and local newspaper are in the yards checking prices as trade progresses (Omaha Livestock Exchange)

In areas with numerous dealers, buying stations, auctions, and packers who buy direct, special Market News Branch offices collect information by phone several times daily.

Throughout the day buyers and sellers at markets, ranchers, farmers, and feeders obtain accurate and unbiased information on receipts, market activity, and prices at any market. Salesmen and packer buyers at the Missouri River markets naturally are interested in prices established early at eastern markets. Because of different time zones, eastern markets normally open an hour before the river markets.

At each market, information gathered there or received by wire from other markets is posted for all to see and made available to local radio stations and papers. Major news services edit market news received, according to the area served, then send it by teletype to radio stations and newspapers.

On which media do farmers and feeders most depend as a source of market information? Numerous surveys have indicated they depend most on radio. Television provides market *summaries* but cannot be as timely as radio.

21

MARKET CLASSES AND GRADES

Livestock are grouped into classes and grades for sale purposes for a number of reasons (1) Reports of sales and prices from distant markets can be more accurately interpreted (Figure 21-1) (2) Prices can be quoted and sales made by phone, wire, or mail (3) Grades which are applied to carcasses or meat cuts serve as a quality guide to the consumer

A *market class* is defined as a group of animals separated according to *use* The major classes are *slaughter* and *feeder*, whether cattle, sheep, or hogs As the titles imply, animals in the slaughter class are intended for slaughter and feeders are being sold for further feeding A third group, *stockers*, is often differentiated as a separate class in cattle or sheep, though most people think of stockers collectively with feeders

The stocker class, when the designation is used, usually includes relatively low quality cattle or sheep that will be fed a low quality ration Examples would be "stocker cows," aged beef cows that may have been culled from a range herd and purchased by a Corn Belt farmer in the fall to utilize crop aftermath—new seeding, corn stalks, fallen ears, etc Most such cows are pregnant when purchased, calve early, and are sold for slaughter in early summer when prices of low quality beef are relatively high "Stocker ewes" are handled similarly The term "stocker calves" usually describes medium or lower quality, light weight, *feeder calves* which, because they are relatively low in quality and light, will probably be grown on cheap feed, such as crop aftermath and silage, before being put on a high energy ration for fattening

Subclasses within the major classes are divided according to age, sex, sex condition (steer vs bull vs stag), and weight

Market *grades* are further subdivisions of the subclasses Animals are grouped according to *relative merit* Among feeders, the major criteria is *conformation* Among slaughter animals, both *conformation* and *finish* are considered

PACKING POINT HOG PRICES

(Monday's quotations provided by plants represented)

ht / loines	Fort Dodge No. 1	Fort Dodge No 2	Fort Dodge No 3	Ottumwa No. 1	Ottumwa No 2	Ottumwa No 3	Mason City	Waterloo U S No. 1-2	Austin No. 1	Austin No. 2	Austin No 3	Storm Lake
25	$....	$12 90	$....	$....	$13 25	$....	$13 50	$13 40-14 05	$....	$13.15	$....	$10 75-11 25
25	....	13 90	...	....	14 25	....	14 50	14 40-15 05	....	14 15	....	12 75-13 25
90	..	14 90	....	....	14 75	....	15 50	15 40-16 05	..	15 15	...	14 75-15 25
40	16 30	15 90	15 50	..								
40	16 90	18 40	16 00	16								
20	16 80	16 40	16 00	16								
00	16 80	16 40	16 00	16								
80	16 60	16 20	15 80	15								
60	16 40	16 00	15 60	15								
40	16 20	15 80	15 40	15								
20	16 00	15 60	15 20	15								
00	15 80	15 40	15 00	15								
75	15 60	15 20	14 80	15								
50	....	....	..	14								
25	...	....	....	14								
8	No 1-3											
75	15 40	15 00	14 60	15								
50	15 15	14 75	14 35	14								
25	14 90	14 50	14 10	14								
00	14 65	14 25	13 85	14								
75	14 40	14 00	13 60	14								
50	14 15	13 75	13 75	13								
00	13 90	13 50	13 10	13								

quotations are for the full ra
ty quotations are for No. 2 g
e quotations
nes quotations for 34 grades
cuts over or under 34 per cent

LIVESTOCK MARKETS

Hog Receipts

	Monday (Est)	Wk Ago	Yr Ago
*Interior Iowa So Minn	65 000	63 000	55 000
12 Public Markets (salable)	90 000	71,400	77,900

*Saturday receipts, 34 000

Sheep Receipts

	Monday (Est)	Wk Ago	Yr Ago
**Interior Iowa-So Minn	3 500	4 100	3 800
12 Public Markets (salable)	33,800	30 600	32 400

*Saturday receipts, 3,800

Hog Quotations

Barrows-gilts	Int Ia So. Minn	Terminal Markets — Chicago	Sioux City	Omaha	E St. Louis
U. S No. 1					
180-200 lb	$ ..	$	$.... ...	$.. ..	$17 35-17 60
200 220 lb	16 25-17 00			16 75-17 00	....
				75-17 00	....

Omaha	E St. Louis
. ....	....
. ....	. .. .
. ....	....
. ....	. .. .
. ....	16 75 17 00
. ....	16 25 17 00
. ....	15 75 16 50
. ....	15 25-16 00
50 17 00	17 00-17 50
75-17 00	17 00-17 50
75-17 00	16 75-17 50
5-16 50	16 75-17 10
5-18 50	18 25-17 10
5-16 50	15 75 16 85
0 15 75	15 25 18 00
0 16 75	18 85-17 25
0 18 75	16 85-17 25
0-16 75	16 50-17 25
5-16 50	16 00-17 00
. .	14 50-14 75
0-14 75	14 50 14 75
0 14 50	14 00 14 75
0-14 00	13 50-14 25

ing plants within the
ents by nine or more

port on Interior Iowa
of animals originating
southern Minnesota.

Cattle Quotations

SLAUGHTER CATTLE AND CALVES

STEERS	Chicago	Sioux City	Omaha	Kansas City
Prime, 900-1,100 lb	$24 00-25 75	$23 25-24 50	$23 50-24 25	$.... ....
Prime, 1,100-1,300 lb	23 75-26 00	23 25 24 50	23 25-24 25	.. . .
Prime, 1,300-1,500 lb	23 00-26 00	22 75 24 25	22 50-24 00	.. ..
Choice, 900-1,100 lb	23 25-24 75	22 00-23 50	22 25-23 75	22 25 23 75
Choice, 1,100-1,300 lb	22 75-24 50	22 00-23 25	21 75-23 75	22 00-23 75
Choice, 1 300-1 500 lb	22 00-24 00	21 75-23 25	21 25-23 50	21 50-23 50
Good, 700- 900 lb	21.00-23 00	20 75-22 25	20 00-22 25	21 25-22 50
Good, 900-1,100 lb	21 00-23 00	20 75-22 25	20 00-22 25	20 75-22 50
Good, 1 100-1,300 lb	20 75-23 00	20 75-22 00	10 50 22 25	20 00-22 50
Standard all weights	19 25-21 00	18 00-21 00	18 00-19 75	18 00-21 25
Utility all weights	18 50-19.25	....	. .. . ..	17 00-18 00
HEIFERS				
Prime 800-1 000 lb	.. ..	23 00-23 50	23 50-24 25	.. ..
Choice, 600- 800 lb	23 00-24 00	22 00-23 25	22 50-23 75	22.25-23 50
Choice 800-1 000 lb	22 75-24 00	22 00 23 25	22 25-23 75	21 50 23 50
Good 500-700 lb	..	20 75-22 25	20 00-22 50	20 50-22 75
Good 700 900 lb	20 75 23 00	20 75-22 25	20 00-22 50	20 25-22 50
Standard all weights	18 50-20 75	18 00-20 75	18,00-20 00	17 50-20.50
Utility all weights	16 50-18 50	....	17 50-18 25	16 00-18 00
COWS: (all weights)				
Standard	17 50-19 00	..	.. ..	..
Commercial	15 00-17 50	16 50 17 50	16.50-17 25	16 50-18 00
Utility	15 25 17 50	16 25 17 25	15 75-16 75	15 75-17 00
BULLS (yearlings excluded)—(all weights)				
Commercial	18 00-21 25	18 00-20 00	18 00-20 50	17 25-18 75
Utility	19 00 21 25	18 00-20 50	18 00 20 25	17 50-19 25
Cutter	18 00-20 50	16 50-19 00	17 00-18 00	15 75-17 50
CALVES (500 lbs down)				
Choice	....	....	....	21 00-25 00
Good	....	....	....	20 00 22 50
Commercial	....	....	.. . .	16 00 21 00
VEALERS (all weights)				
Choice	....	....	26 00-30 00	25 00 30 00
Good	.. ....	....	23 50 26 00	22 00-26 00
Commercial	..	.. ..	19 00 24 00	18 00-22 00

FEEDER AND STOCKER CATTLE AND CALVES

STEERS:	Chicago	Sioux City	Omaha	Kansas City
Choice, 500- 800 lb	$24 00-29 00	$23 50 29 00	$23 75-29 50	$23 25-29 00
Choice 800-1 050 lb	22 50-25 00	20 00-25 00	21 75-24 00	21 50-24 50
Good 500-800 lb	22 00-26 00	21 50-25.00	21 50 25 50	21 25-28 25
Good 800-1 050 lb	21 00-24 00	20 50-22 50	20 50 23 75	20 00 23 50
Medium 800-1 000 lb	18.50-23 00	17 50-20 50	18 00-23 00	18 00 24 00
Common 500-900 lb	....	....	17 00-19 00	16 50-19 00
HEIFERS (500-750 lbs)				
Choice	....	22 00-25 50	21 50-25 50	22 00 25 50
Medium and good	....	18 00-22 50	17 50-22.00	17.50-24 00
COWS (all weights)				
Medium and good	....	....	15 00-17.50	15 00-18.00
CALVES (Steers) - (300-500 lbs)				
Good and choice	....	24 50 30 00	25 00-32 50	23 50-33 00
Medium	....	21 50-25 00	22 00-26.00	19 50-25 00
CALVES (heifers) - (300 500 lbs)				
Good and choice	....	20 50-27 00	22 00 30 00	22 50-28 50
Medium	. . ....	18 50-23 00	15 00-23 00	17 00-23 00

Sheep Quotations

SPRING LAMBS	Chicago	Sioux City	Omaha	Kansas City
Prime	$19 50 20 00	$18 50-19 25	$18 00-19 25	$17 75-18 75
Choice	18 50-19 50	17 25 18 50	17 00-19 25	17 00-18 25
Good	17 50 18 50	16 25-17 25	.. . .	16 50 17.25
LAMBS (shorn)				

Figure 21-1. A market report lifted from a daily newspaper. Note the various classes and grades listed. A knowledge of these is essential for the prices to be meaningful to the reader. (Des Moines Register, Tuesday, June 6, 1961.)

21.1 Development of Classes and Grades

The use of classes to differentiate and describe animals probably developed early in the history of livestock trading There were also terms, no doubt, that were rather uniformly used to denote relative quality

Market classes as known and used today have simply developed from common usage, but are surprisingly uniform across the country Some discrepancies are noted A "vealer" in New Orleans may be called a "calf" in St Paul A "feeder pig" in Indiana may be called a "shoat" in Arkansas or a "stock hog" in North Dakota But the class designations have real meaning to livestock traders and discrepancies which do exist interfere little with effective trading

Grades in use today have been developed and standardized by the USDA since 1916 Picture standards and verbal descriptions of grades are available from the USDA for nearly all classes of meat animals They have been continually and severely criticized by many segments of the meat industry and have been revised many times Their use is voluntary, however, and many producers, traders, and consumers depend on them as a standard of quality

Anyone is free to apply class and grade designations to live animals Continued confidence in those who use these designations, however, obviously depends on their experience, knowledge, and ability to discriminate Application of USDA grades to carcasses, however, must be done by a designated USDA employee (see Section 24 4) This person also has responsibility for checking the market class of the carcasses involved If he finds a "yearling" among a group of "lamb" carcasses he must designate it as such

Other carcass grades, besides those of the USDA, are used Many packers have a private grading system, including grade names which may be copyrighted and which are applied by their own employees Public confidence in these grades, too, depends on discrimination exercised in applying the grades to carcasses or cuts

21 2 Beef Classes

The major classes, slaughter and feeder, as well as stocker, were previously discussed Other classification criteria will be discussed here, with reference made to Table 21-1

Subclasses are further defined below, recognizing there may be some discrepancy in interpretation among various sections of the United States

Steer— a male bovine castrated when young prior to the development of the secondary physical characteristics of a bull

Heifer— an immature female bovine that has not developed the physical characteristics of a cow

Table 21-1. Commonly Used Class Designations of Beef Cattle

Feeder		
Sex and sex cond.	Age	Weight range
Steers	Calves	300-500
	Yearlings	500-800
	2-yr-olds	800-1050
Heifers	Calves	300-500
	Yearlings	500-750
Cows	Young	750-1200
	Aged	
Bulls, stags, etc.		

Slaughter		
Sex and sex cond.	Age	Weight range
Steers		500-1500
Heifers		500-1100
Cows	Young	
	Aged	
Bulls	Young	
	Aged	
Stags		
	Calves	Under 500
	Vealers	Under 250

Cow— a female bovine that has developed, through reproduction or with age, relatively prominent hips, a large middle, and other physical characteristics typical of mature females.

Bull— an uncastrated male bovine.

Stag— a male bovine castrated after it has developed or begun to develop the secondary physical characteristics of a bull.

Calf— bovine usually between three and eight months of age (up to 10 or 12 months for feeders).

Vealer— bovine under three months of age (intended for slaughter) and having subsisted largely on milk or a milk substitute.

Heiferette—a term sometimes used to describe a heifer which calved young, perhaps at two years of age, then was quickly fattened for slaughter. Carcass traits are between those of a heifer and cow.

Classes and subclasses listed under "sex and sex condition" and under "age" are commonly used in market reports (Figure 21-1). Animals in certain of these classes may be absent, or present in small numbers, at some markets. Relatively few, if any, 2-year-old slaughter steers would be sold at Tulsa or Oklahoma City, for example, and certain classes of cattle are relatively rare at some eastern markets. Age subclasses other than those listed in the table may sometimes be used.

Calves and vealers, for slaughter, are often not differentiated as steers, bulls, or heifers, since the secondary sex characteristics have not developed to the point of influencing carcass traits at the time of slaughter.

Weight groups are usually divided into 200- or 300-pound increments.

Classes do not denote whether animals are of beef, dairy, or dual-purpose breeding, or whether they may be crossbreds. Many slaughter cows

have been culled from dairy herds, most vealers are of dairy breeding There are also many steers of dairy and dual-purpose breeding, since only a small percentage of the males are kept as bulls

21.3 Sheep Classes

Table 21-2 summarizes the most common classes and subclasses of sheep Nearly all feeder sheep are lambs Drastic reduction in slaughter value of sheep over a year of age almost dictates that lambs be sold for feeding before eight or nine months No designation is usually made between ewes and wethers, unless the animals are two years of age or older A ram is often discounted in price (Section 23 3) Weight groups given in market reports are usually divided into ten-pound increments

Table 21 2 Commonly Used Class Designations of Sheep

Sex and sex cond	Age	Weight range
	Lambs	55 90
Ewes	Young	
	Aged	

Sex and sex cond	Age	Weight range
	Lambs	70-120
	Lambs (shorn)	70-120
	Yearlings	100-130
Ewes	Young	100-180
	Aged	
Rams	Young	120 300
	Aged	

Most yearlings intended for slaughter are just slightly over a year of age In most cases it was probably not intended that they be so mature before being sold for slaughter Ewes and rams intended for slaughter have usually been culled from flocks for various reasons They may range considerably in age or weight, though most would be relatively old

Some of the terms used to describe certain classes or groups of sheep are given below Note the similarity of some definitions to those given for cattle

Wether— a male ovine (sheep) castrated young, before secondary sex characteristics develop
Ewe— a female ovine of any age
Lamb— ovine under one year of age
Yearling—ovine over one year of age, but under two Loss of the center pair of incisors is a guide on live animals Ossification of the "break joint" above the front pastern, is a guide on carcasses
Ram— an uncastrated male ovine
Stag— a male ovine castrated after it has developed or begun to develop the secondary physical characteristics of a ram.

Because age is so important, USDA graders check indicators of age on the carcass. Lamb carcasses have a "broken" break joint, narrow, reddish rib bones, a relatively narrow forequarter, and a light red, fine-textured lean. Yearling mutton carcasses may show either break joints or spool joints at the front pastern. They have moderately wide rib bones with only traces of red, a slightly wide forequarter, and slightly dark red, coarse lean. Mutton carcasses (two years and over) show spool joints, wide and white rib bones, a wide forequarter, and dark red, coarse lean.

21.4 Hog Classes

Because hogs are nearly all handled similarly—on a high energy ration for quick marketing—there are few age classes as compared to cattle. Common classes are charted in Table 21-3.

Table 21-3. Commonly Used Class Designations of Hogs

Feeder			Slaughter		
Sex and sex cond.	Age	Weight range	Sex and sex cond.	Age	Weight range
	Pigs	30-180	Barrows and Gilts		160-360
	Shoats	80-180	Sows	Young	250-600
				Aged	
			Boars	Young	
				Aged	
			Stags	Young	
				Aged	

Feeder pigs are all young, and are not sorted by sex. They are usually listed in market reports in weight increments of about 20 pounds. Shoats is a term used in many areas to describe relatively heavier and older feeder pigs.

Barrows and gilts are sold together for slaughter. They are sometimes referred to collectively as butchers or market hogs. Most slaughter groups contain about 40 per cent gilts; there is little difference in carcass merit of barrows and gilts. Prices are usually given for 20-pound weight brackets.

Many young sows, which have farrowed only one or two litters, are sold for slaughter. They are often worth almost as much per pound as immature gilts. Hog raisers like to sell them before they get too heavy. Large, more mature sows, are too expensive to maintain in most sow herds.

Because boars are heavily discounted when sold for slaughter, most are castrated, then sold a month or so later as stags Some boar carcasses carry a strong, offensive odor This is not true of bulls and rams

For clarity and comparison, various class terms are briefly defined below

- Barrow—male pig (porcine, or swine) castrated before secondary sex characteristics develop
- Gilt— female pig under a year of age and before farrowing a litter of pigs (Some refer to a sow that has farrowed once as a "one litter gilt)
- Sow— female pig over a year of age, or which has farrowed one or more times
- Boar— uncastrated male pig
- Stag— male pig castrated after it has developed or begun to develop secondary sex characteristics

21.5 Feeder Grades

The USDA offers official grade standards for feeder lambs and cattle, but not for pigs These are discussed in Chapter 8, Selection of Feeders

21 6 USDA Grades for Slaughter Animals and Carcasses

Though official USDA grades are applied only on carcasses, by a govern mental grader, they also serve as a basis for grading live animals intended for slaughter Verbal descriptions for live animal and carcass grades are printed in the Federal Register or Code of Federal Regulations, and are reprinted for distribution by the USDA Standard grade pictures of animals and carcasses are likewise available (see Appendix)

The ability of buyers and sellers to assign grades to live animals varies, and depends partly on experience A thorough discussion of this topic, with supporting data, is presented in Section 23 6 In general, buyers and sellers, as well as USDA market reporters, do have a good concept of live animal slaughter grades and are able to make transactions and report sales with considerable accuracy Note that live grades are used in the price quotations in Figure 21-1

The procedure for applying grades on carcasses during processing in the packing plant is discussed in Section 24 4 It is emphasized that the use of the USDA carcass grades (and a USDA employee to apply them) is voluntary on the part of the packer It is a service that is available to the packer on a cost basis Because many consumers and retailers depend on USDA grades as a standard of quality, especially with beef and lamb, many packers feel it advantageous to employ this service (Compulsory grading was employed during the war periods of 1942-47 and 1951-53)

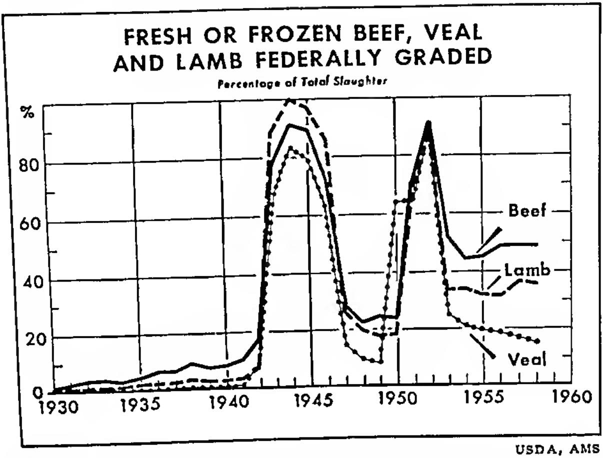


Figure 21-2. The percentage of beef, lamb, and veal carcasses federally graded has been fairly uniform in recent years. Federal grading of most carcasses was mandatory during much of World War II and during the Korean War.

Since 1953, about 45 to 50 per cent of the beef slaughtered each year has been federally graded, compared to about eight per cent in 1940 (Figure 21-2). Naturally, most of the beef selected by packers to be USDA graded is in the higher grades.

The USDA has considered dropping the service of grading lamb carcasses because of failure of industry members to agree on revision of the standards.

Though standards are available for pork carcasses, no pork carcass grading is done by USDA employees. There is relatively less merit in grading pork carcasses for two reasons. (1) Since hogs are nearly all fed for early marketing, there is less variation in age and weight and carcass quality traits influenced by age and weight. (2) Most pork is broken into wholesale cuts in the plant, cuts are trimmed to a uniform fat depth, and many cuts are cured, smoked, and otherwise processed. Recognizing quality differences that exist among various parts of carcasses, there may be more merit in grading pork cuts than pork carcasses.

Among lambs, there is likewise considerable uniformity in slaughter age and weight, so less variation in carcass quality.

Amoog beef cattle, however, there is an extremely wide range in slaughter age, weight, and finish, because of the vast number of feeding programs followed in raising beef cattle This, alone, is justification for using a grading system Further, most beef is sold fresh, with little processing or trimming, and is moved from packer to retailer as "quarters" rather than cuts

Because USDA grades are developed and used to serve the public, includiog producer, processor, retailer, and consumer, and because their use is generally not required, changes are periodically made in grade names, specificatioos, or rules of application Therefore, any discussioo of a USDA grading system must be based on the *principles* of carcass grading Grade specifications and staodard pictures, as well as the names of the grades, must be considered "temporary"

21.7 What Do USDA Carcass Grades Appraise?

The purpose of carcass grading is to categorize carcasses according to merit This is the same reasoo that wool, potatoes, corn, and other commodities are graded But a meat carcass is a rather large unit, compared to a potato or a kernel of corn, and there may be a large quality gradient among various parts of the carcass

Because a carcass is a large unit and various parts may differ considerably in value, carcass grades are based on two different considerations, both important. One is the *quantitative proportion of the various parts* Is there a high proportion of loin, nb, or rouod, the expensive cuts on a beef carcass, for example? And are these cuts "plump" or "bulging," with a high proportioo of lean meat in relatioo to bone and/or fat? The other major coosideration, probably most important to the consumer, is the *qualitative evaluation of the edible tissue*, believed to be associated with palatability The latter would include texture of lean, iotermixture of fat witb lean, and other characteristics These two major considerations might be more briefly termed "conformatioo" aod "quality"

Because these two considerations, conformation and quality, are *not perfectly correlated* and because each is composed of many items which must be *subjectively appraised*, a grade applied to a carcass is based oo a subjective decisioo by the grader Because conformation aod quality are not perfectly correlated, ooe must often be balanced against tbe other before a grade decision is reached USDA specifications attempt to describe the extent to which one can compensate for tbe other However, there are apparent and real limitations in the use of a single set of carcass grades as indicators of carcass merit.

Obviously the conformatioo characteristic is of great concern to the retailer, who breaks beef and lamb carcasses into cuts and assigns a

different price to each cut. A carcass yielding a higher proportion of loin, rib, and round should, from his standpoint, grade higher. The consumer, however, who is appraising a *single cut* of meat (that may even have been trimmed) is primarily interested in an appraisal of the *quality* of that particular cut.

This discussion suggests use of a dual grading system, one designation for quality and another for "cutability," or proportion of retail cuts. The USDA has completed studies on the practicability of such a system,[1] and began using the system on a trial basis July 1, 1962. *Within* a quality grade such as choice, for example, there are six *numerical* grades based on the expected proportion of retail cuts. Grade One carcasses have little fat to be trimmed off and yield a high proportion of retail cuts. Grade Six carcasses have high proportions of fat.

Because carcass grading is still a subjective process, much attention is currently directed toward developing more objective techniques for appraising conformation and quality in carcasses, and also in live slaughter animals. Certain techniques will be discussed in Chapters 23 and 26.

21.8 Grades for Slaughter Cattle and Beef Carcasses

Grade designations used by the USDA for slaughter cattle and beef and veal carcasses at the time of this writing (July 10, 1962), along with the dates of the most recent revisions, are given in Table 21.4. Approximate age limitations, in months, are given in parentheses. Age is appraised on live animals by the teeth, and on carcasses by meat texture, size of bone, and whiteness of bone.

Cows, stags, and bulls are not eligible for the prime grade; a few grade choice unless they are exceptionally young and high in quality. The standard grade is reserved for animals under four years of age and their carcasses. The commercial grade is limited to cattle over four years of age and their carcasses, except for bulls and stags, where there is no age specification. There is no age limitation on other grades.

[1] AMS, USDA, *Bull. 416*, Nov. 1960, and from private communication.

Table 21-4. U.S.D.A. Grades for Beef and Veal

Steer & heifer June, 1956	Cow June, 1956	Bull & stag June, 1956	Calf & veal May, 1957
Prime (36)			Prime
Choice (42)	Choice (42)	Choice	Choice
Good (48)	Good (48)	Good	Good
Standard (48)	Standard (48)		Standard
Commercial	Commercial	Commercial	
Utility	Utility	Utility	Utility
Cutter	Cutter	Cutter	
Canner	Canner	Canner	Cull

Excerpts from the current specifications for choice grade slaughter steers, heifers, and cows are . . "moderately low set and compact . . . moderately thick in natural fleshing and moderately wide over the back and loin. . . . Cattle over 30 months of age have a thick covering of fat over the crops, back, ribs, loin, and rump . . . Cattle 18 to 30 months of age carry a moderately thick fat covering. . . ."

Excerpts from specifications for choice beef carcasses include . . . "moderately blocky and compact and moderately thick-fleshed . . . loins and ribs are moderately thick and full and the rounds are moderately plump. . . ." Finish specifications are in relation to age; older cattle must carry more finish Grade specifications for the prime grade generally do not include the term "moderate"; the term "slightly" is used for the good grade.

It is impossible to develop ability and skill in grading slaughter animals or carcasses from a text even with the aid of pictures. Much practice and experience are needed.

What percentage of the mature beef cattle which are slaughtered grade choice or prime? See Figure 21-3. This also indicates the percentage of the major market classes—steers vs. heifers vs. cows and bulls.

21.9 Grades for Slaughter Sheep and Lambs and Their Carcasses

Grade designations currently used by the USDA for slaughter sheep[2]

[2] Technically, according to USDA criteria, a sheep is an ovine, usually over 24 months of age, that has cut its second pair of permanent incisor teeth.

Figure 21-3. Approximate percentages of mature slaughter cattle, by class and by grade

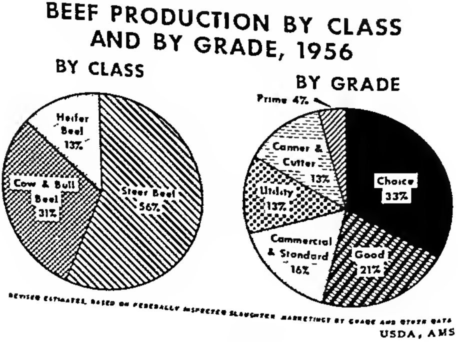


Table 21-5. U.S.D.A. Grades for Sheep

Lamb and yearling Nov., 1960	Mutton Nov., 1960
Prime	
Choice	Choice
Good	Good
Utility	Utility
Cull	Cull

(called "mutton" in the carcass), yearlings, and lambs, as well as for their corresponding carcasses, are given in Table 21-5.

Animals over two years of age, or their corresponding carcasses, are not eligible for the prime grade. Though age of carcass is appraised by the USDA grader, it is a criterion for *classification,* not grading, and is discussed in Section 21.3.

Prime lambs are described as ". . . moderately low-set and blocky and thickly fleshed. They are moderately wide over the back, loin, and rump . . . ." In contrast, cull lambs are described in USDA standards as ". . . extremely rangy, angular, and thin-fleshed, and extremely narrow and shallow bodied. . . ."

Prime carcasses must be ". . . moderately wide and thick in relation to length . . . have moderately plump and full legs; moderately wide and thick backs; and moderately thick and full shoulders. . . ." Cull carcasses are ". . . extremely angular . . . extremely thin-fleshed . . . legs are extremely thin and concave . . . flesh is soft and watery. . . ."

21.10 Grades for Slaughter Hogs and Pork Carcasses

Grade designations currently used by the USDA for slaughter hogs and pork carcasses, as well as the basic specifications for the carcass grades are given in Table 21-6. Live weights are calculated from carcass weights given, so specifications may be more meaningful.

Because no USDA graders are employed to grade pork carcasses, the above specifications serve primarily as a guide to producers and processors in evaluating relative carcass merit, as well as a guide to development of private grade designations by packers. Carcass specifications given in Table 21-6 are only a basic guide; an extensive verbal description of required traits is also provided by the USDA for live hogs and carcasses. U.S. No. 1 slaughter hogs ". . . have an intermediate degree of finish . . . are moderately wide over the top . . . width through hams is nearly equal to shoulders . . . hams moderately thick and full with a slightly thick fat covering. . . ." The corresponding U.S. No. 1 carcasses ". . . have near the minimum degree of finish required for the production of acceptable quality cuts . . . yield of lean cuts in relation to car-

Table 21 6 U S D A Grades for Hogs and Specifications for Carcasses (April 1958)

Live weight lbs (70% yield)	Carcass weight R Carcass length	Average backfat thickness inches[2]				
		U.S No 1	U.S No 2	U.S No 3	Medium	Cull
Barrows and gilts						
170 or less	<120 lbs or 27 in	1 2 1 5	1 5 1 8	1 8 or more	0 9 1 2	<0 9
171 234	120 164 or 27 29 9	1 3 1 6	1 6 1 9	1 9 or	1 0 1 3	<1 0
235 299	165 209 or 30 32 9	1 4 1 7	1 7 2 0	2 0 or	1 1-1 4	<1 1
300 or more	210 33 or more	1 5 1 8	1 8 2 1	2 1 or	1 2 1 5	<1 2
Sows						
Any weight or length		1 5 1 9	1 9 2 3	2 3 or more	1 1 1 5	<1 1

[1] Length measured from the forward po nt of the aitch bone to the forward edge of the first rib

[2] Average of measurements made opposite the first and last ribs and last lumbar ver tebra

cass weights is slightly high hams are usually moderately thick plump and smooth bellies are moderately long and smooth Carcasses in the thinner half of U S No 1 finish specifications but with thin soft bellies should be graded Medium Those in the fatter half with other traits similar to U S No 2 should be graded U S No 2

Briefly the grades can be described as U S Nos 1 2 and 3 are optimum finish slightly overfinished and extremely overfinished respec tively Medium is slightly underfinished and Cull is extremely under finished

Specifications used to describe various grades of pork carcasses repre sent a more objective approach than those used for lamb or beef grades This is possible because (1) slaughter hogs are more uniform in age and weight and (2) much research with pork carcasses has shown high cor relations between specifications used and percentage of lean cuts or other conformation and quality traits

Canada has employed a compulsory federal grading system for many years based on similar specifications and has credited it with much im provement in pork carcass quality Canadian packers have maintained substantial price differentials among the grades and the Canadian govern ment has paid a premium to producers of the top grades since 1944 Canadian grades and specifications revised October 5 1959 are given in Table 21 7 Live weights are calculated from carcass weights given

21 11 Private Meat Grading

Many processors as well as some retailers employ their own system of grad ng meat products including carcasses cuts or processed meats such as ham or bacon

Packers may have fewer grades or more depending on the range in quality they handle and the degree of categorization they and their customers want. Some apparently use the USDA specifications and cate

Table 21-7. Canadian Pork Carcass Grades and Specifications*

Grade	Live wt., lbs. (70% yield)	Carc. wt., lbs.(warm)	Length, in.	Maximum fat tolerance, in. Shoulder	Loin
A	193-214	135-150	29-29.5	1.75	1.25
	214-243	150-170	29.5-30	2.00	1.50
B	179-214	125-150	28-28.75	1.75-2.25	1.5-1.75
	214-257	150-180	29-30	2.25-2.50	1.75-2.00
C	179-257	125-180		overfinished	
O	under 129	under 90, or underfinished of all wts.			
Light	129-177	90-124			
Heavy	259-279	181-195			
Ex. Heavy	280	196 and over			

**Canadian Livestock Products*, Sept.-Nov. 1959, Meat Packers Council of Canada, Toronto.

gories, but apply their own grade names. Review your local newspaper for examples of private grades, as well as USDA grades, used in retail advertising. You are probably familiar with many.

Accuracy and dependability of private grades depend, just as the USDA grades depend, on ability of the grader and degree of discrimination. Many retailers and consumers prefer USDA grades because they were applied by a clearly "unbiased" person, not an employee of the packer. Packers who use a private system want to establish and maintain respect for their top grades, however, so are likewise concerned that their employed graders be accurate and discriminating.

Private carcass grading may be less costly since a packer employee does it. If he is not fully employed in grading, his labor may be used elsewhere. Also, where USDA graders are used, a packer grader usually reviews his work or else precedes him to designate carcasses he wants graded.

A private system may be more meaningful in a particular area or for a particular line of meat products than USDA grades, which are standard for the entire country. Large processors, with intensive advertising, may effectively establish one of their top grades as a "trademark of dependable quality." It is to compete against this that small packers like to use USDA grades. They feel consumers also respect these as "trademarks of dependable quality."

A significant advantage of private grading is that it can be and often is employed to grade *cuts* instead of carcasses. Because of the *quality* gradient that exists between or among parts of carcasses, or before and after trimming or processing, grading of cuts is often worthwhile. A loin from an extra heavy barrow carcass (that would grade U.S. No. 3) might be trimmed of excess backfat, and sold as chops labelled "Jones Meaty Select." The shoulder from the same carcass, however, would probably carry too much fat *between* muscles and effective trimming to the "Meaty Select" grade would not be possible. The bacon, too, would probably be rather thick and fat so would be sold as "Jones Pride" or "Jones Budget Bacon."

22

CYCLES IN LIVESTOCK SUPPLIES AND PRICES

Price is a function of supply and demand Supplies of livestock tend to fluctuate in three rather distinct cyclic patterns long-term, seasonal, and weekly Long-term cycles and the factors which cause them will be discussed in Section 22 1 Seasonal cycles, which tend to occur annually, vary among species and between feeder and slaughter livestock A major portion of the chapter, Sections 22 2 to 22 8, is therefore devoted to these cycles A discussion of weekly cycles, most noticeable at terminal markets and with slaughter livestock, completes the chapter

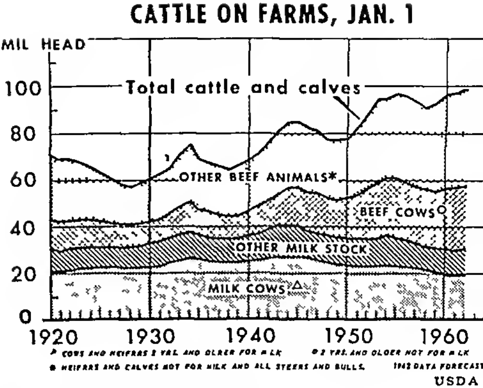
Factors which comprise demand differ between feeder and slaughter livestock Also, since the demand for feeders tends to follow more of a seasonal pattern than does the demaod for slaughter livestock, the effects on price are markedly different Because demand is so important in helping to establish price, producers, processors, and retailers should be alert to factors which influence demand and should be aware of any changes in demand (Chapter 25)

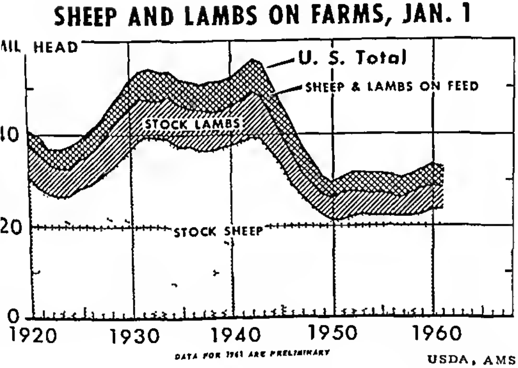
Other fluctuations in livestock supplies and prices, unrelated to the three types of cycles, certainly do occur There are reasons, however, for their occurrence Perhaps an understanding of the causes of cyclic patterns will provide a clue for understanding, or even anticipating, these other fluctuations

22.1 Long-Term Cycles in Livestock Numbers

Figure 22-1 shows the long term cyclic changes in cattle, sheep, and hog numbers In cattle, six to eight years of increase in cattle numbers is usually followed by four to eight years of decline, a total of 10 to 17 years per cycle Distinguishable cycles are closer for sheep and hogs A continued upward trend has occurred during the time covered by the graph, because of continued population growth in the United States and a gradual increase in level of living, reflected in meat purchases

Why do these cycles occur? Let us discuss any one of the cattle cycles, because they are most distinct, beginning at a low point. A low "supply" of beef cattle meant that beef production was low—lower per capita than





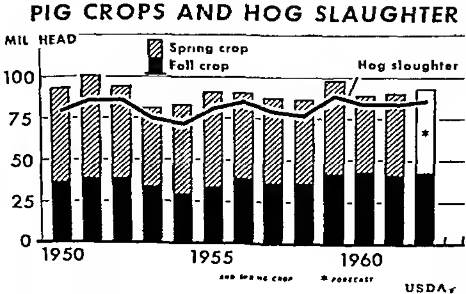


Figure 22-1. Long term cycles in livestock numbers Note the difference in length of cycle among cattle, sheep, and swine

in previous years Hence, beef prices were no doubt high in relation to other commodities Cattle raising and feeding were profitable

More people started raising cattle, those who already had cow herds kept more heifers to increase their herd size

But it takes several years for larger cow herds to increase the amount of beef on the consumer's table The heifers have to mature, be bred, and calve, and the calves then have to grow and be fed for slaughter During this time beef prices continue high and the beef business continues to appear attractive So cattlemen continue expansion and still more enter the business

Finally, in six, seven, or eight years, supply equals or surpasses demand Beef production has expanded faster than population Beef prices drop Raising beef cattle becomes less profitable

Raisers would like to decrease numbers But there is a snag Reducing the herd size means culling and selling more old cows for slaughter or keeping fewer replacement heifers and sending more, directly or indirectly, to slaughter This puts more beef on the market, decreasing prices even more So reductions in cow herds tend to occur less rapidly than desired

Reductions continue as long as beef prices appear unfavorable and until, in time, supply is enough lower than demand that prices increase Then the cycle repeats The pendulum swings—profit incentive creates momentum in cattle expansion, then the burden of low prices creates momentum in decreasing cattle numbers

Certainly other factors influence the regularity, length, and smoothness of the cycles Since each species represents a meat product, supplies and prices of one influence supplies and prices of the others Wars, depressions, prolonged drouth, feed supplies, etc, also exert obvious influence Though meat supplies may be high and prices low, extremely abundant supplies of cheap feed may encourage livestock feeding, increasing total meat supply and causing still lower livestock prices Such a situation existed in the late 1950 s

Sheep numbers are drastically influenced by certain economic factors, though some cyclic patterns are still distinguishable Sheep numbers seem to be *inversely proportional* to the farmer's or rancher's economic plight When prices are high and livestock raising is profitable, sheep numbers drop When prices are low, and farming and ranching relatively unprofitable, sheep numbers rise Sheep compete with cattle for a place on farms or ranches—they both eat forage In "high" times cattle will yield more profit per acre, per dollar invested, or per hour of labor In "low" times sheep may be more profitable, requiring less grain and less investment Labor is a bigger item in raising sheep, but a rancher's own labor is not out-of the-pocket cash in low times

It is apparent in Figure 22 1 that sheep and hog cycles are shorter than cattle cycles Why? This is mainly caused by differences in *prolificness*—

age at sexual maturity, gestation period, and number of offspring. *Salvage value* of culled or surplus breeding stock is also a factor.

The earlier discussion of a cattle cycle explained that it took several years for an extra heifer saved for herd expansion to contribute to increased beef supply at the market. Heifers are usually bred at 18 to 27 months of age, have a nine-month pregnancy, and usually give birth to one calf which will probably not be slaughtered for ten months or longer. Contrast this with a ewe which is bred younger, has a five-month pregnancy, and has one or two lambs which may be slaughtered in four to six months. Or compare it to a gilt which is bred at eight months, farrows eight or more pigs at about a year of age and the pigs can be slaughtered in four and one-half to seven months.

Another factor is that swine herds can *expand faster*. Each gilt may farrow four boars and four gilts; the four gilts can go into the breeding herd. A heifer has but one calf, and chances are only 50 per cent that it will be a heifer for the breeding herd. And if it is, the increase in marketable beef is further delayed.

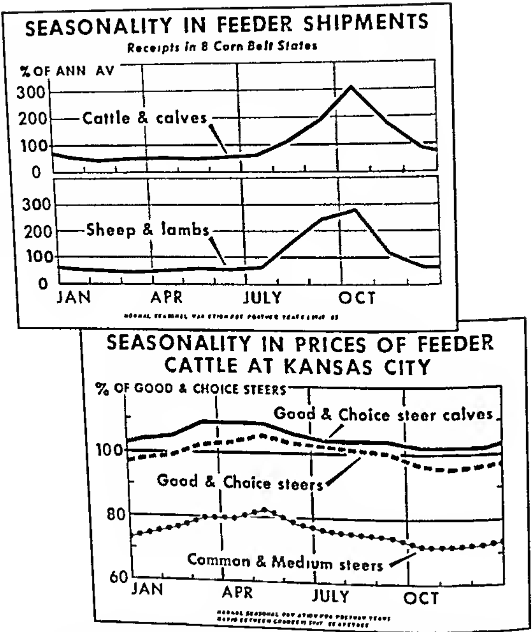
When the time comes to decrease numbers, the hog man can do it faster and usually with less sacrifice. Surplus sows will sell for slaughter at prices only slightly under those for barrows and gilts. Any ewe that has never lambed, however, isn't worth much for slaughter. The price differential for mature cows is also greater than for mature sows, and a cow is a big animal. Cattle raisers have more money invested in their breeding herd than hog raisers, in relation to production, so can lose more if they have to sell off surplus breeding stock at low prices. Hence, they are more hesitant to sell, tending to wait for better prices, and the decline in cattle numbers is delayed.

22.2 Seasonal Cycles

Seasonal cycles tend to repeat themselves year after year, except as influenced by movement of the long-term cycles or other factors. They are usually caused by seasonal weather variation, which affects feed supply as well as the animals, and by reproductive cycles. In some cases seasonal weather extremes dictate that certain livestock production schedules be followed. Though modern housing and equipment may counter these weather extremes, the same schedules are often followed because of habit or tradition. Many examples will follow.

22.3 Feeder Cattle and Lambs

Factors which influence the supplies and prices of feeder cattle and lambs are similar. Figure 22-2 indicates the normal seasonal cycles. Note that heavy movement of feeders occurs in the fall. (See Figure 22-5 for feeder lamb prices.)



USDA, AMS

Figure 22 2 More than half of the yearly movement of feeder cattle and lambs to the Corn Belt takes place in a few fall months Graphs are based on earlier years but data for early 1960 s are similar

Why do feeders move in the fall? Calves and lambs are ready to be weaned then Most are born in the spring, in the range areas, and they are five or six months of age by September Advantages of calving or lambing in the spring in these areas are obvious—warm weather and grass for the calf or lamb, lush grass for the cow or ewe for heavy milk production, etc

The rancher doesn't want to sell his calves or lambs before September because they are the *market outlet for his grass* during the entire growing season Yet he likes to have them sold and away from the ranch by late

October, before snow flies, so he will not be forced to feed them harvested, more expensive feed. An exception is the rancher who harvests considerable forage. He will probably winter his calves, at least the steers, on hay, let them graze the following summer, and sell them as yearlings the second fall. Selling feeder cattle and feeder lambs from the range states in the fall months is a naturally advantageous thing to do. Supply of feeder cattle and lambs at markets is a *function of convenient and economical production.*

If a large proportion of feeder cattle or lambs are sold in the fall, why doesn't the price drop sharply? Price is a function of supply and demand. Though supply of feeders has increased, in this case demand has increased also. Corn Belt cattle feeders and feeders in other areas know by October 1, or earlier, what their feed supply will be—grain, as well as hay and silage. Second, they often like to buy cattle or lambs in early fall to clean up forage that would otherwise be wasted—corn stalks, oat stubble, and aftermath of the hay crop. Another reason is that most livestock feeders are also engaged in a general farming operation and need a market for their labor during the winter.

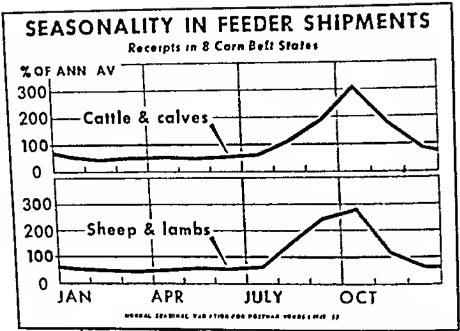
These reasons, and others, help explain why more than six times as many feeder cattle or lambs move through the various marketing channels during any one week in October as during a particular week in early summer.

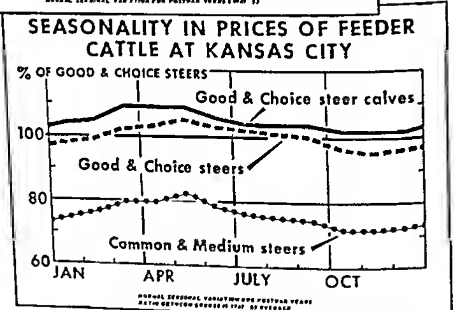
A heavy demand for feeder cattle is usually noted in early spring, as pastures begin to appear lush. This wave of demand moves from south to north as warm weather and spring rains arrive. Though this demand period is of rather short duration, farmers with considerable pasture land often bid too high for cattle so they will have "something to eat the grass." In some cases "growing grass" would be more profitable. This situation is reflected in the higher prices during April and May charted in Figure 22-2 (and Figure 22-5 for lambs), though supply is rather steady from February through July.

Obviously there is trading in feeder cattle and lambs almost continually through the year. Fall born calves and lambs raised in the South are marketed in different seasons. Intensified feeding operations have created a more constant demand for feeders throughout the year. But there continue to be seasonal cycles. Weather extremes in the northern United States, especially in range areas, continue to encourage fall peaks in feeder supply. And these peaks, or valleys, in supply relative to demand are a major influence on price.

22.4 Feeder Pigs

Because many who raise and sell feeder pigs have facilities for farrowing in any season and like to keep these facilities busy, there is a rather steady supply of weanling feeder pigs the year round. Accurate data





USDA, AMS

Figure 22-2. More than half of the yearly movement of feeder cattle and lambs to the Corn Belt takes place in a few fall months Graphs are based on earlier years, but data for early 1960s are similar

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The rancher doesn't want to sell his calves or lambs before September because they are the *market outlet for his grass* during the entire growing season Yet he likes to have them sold and away from the ranch by late

October, before snow flies, so he will not be forced to feed them harvested, more expensive feed. An exception is the rancher who harvests considerable forage. He will probably winter his calves, at least the steers, on hay, let them graze the following summer, and sell them as yearlings the second fall. Selling feeder cattle and feeder lambs from the range states in the fall months is a naturally advantageous thing to do. Supply of feeder cattle and lambs at markets is a *function of convenient and economical production.*

If a large proportion of feeder cattle or lambs are sold in the fall, why doesn't the price drop sharply? Price is a function of supply and demand. Though supply of feeders has increased, in this case demand has increased also. Corn Belt cattle feeders and feeders in other areas know by October 1, or earlier, what their feed supply will be—grain, as well as hay and silage. Second, they often like to buy cattle or lambs in early fall to clean up forage that would otherwise be wasted—corn stalks, oat stubble, and aftermath of the hay crop. Another reason is that most livestock feeders are also engaged in a general farming operation and need a market for their labor during the winter.

These reasons, and others, help explain why more than six times as many feeder cattle or lambs move through the various marketing channels during any one week in October as during a particular week in early summer.

A heavy demand for feeder cattle is usually noted in early spring, as pastures begin to appear lush. This wave of demand moves from south to north as warm weather and spring rains arrive. Though this demand period is of rather short duration, farmers with considerable pasture land often bid too high for cattle so they will have "something to eat the grass." In some cases "growing grass" would be more profitable. This situation is reflected in the higher prices during April and May charted in Figure 22-2 (and Figure 22-5 for lambs), though supply is rather steady from February through July.

Obviously there is trading in feeder cattle and lambs almost continually through the year. Fall born calves and lambs raised in the South are marketed in different seasons. Intensified feeding operations have created a more constant demand for feeders throughout the year. But there continue to be seasonal cycles. Weather extremes in the northern United States, especially in range areas, continue to encourage fall peaks in feeder supply. And these peaks, or valleys, in supply relative to demand are a major influence on price.

22.4 Feeder Pigs

Because many who raise and sell feeder pigs have facilities for farrowing in any season and like to keep these facilities busy, there is a rather steady supply of weanling feeder pigs the year round. Accurate data

are not available on seasonal movement of feeder pigs, since few go through established markets

In heavy corn growing areas demand for feeder pigs of any weight is noticeably heavier at harvest time, especially in years when the corn crop is good Higher feeder pig prices may encourage other hog raisers to sell and movement increases

Because long term hog supply cycles are rather short and move up and down sharply, *they and the factors that cause them* are probably the major influences in establishing feeder pig prices Local conditions also exert an effect

22 5 Supply and Price Relations for Slaughter Livestock

Factors which influence supply of slaughter livestock and prices received for such livestock are the same for all species The first is that *total demand* for meat doesn t change much from season to season Of course there is some variation in consumption especially of individual meat items More stews and roasts are used, for example, in the winter hot dogs and steaks are favorites in the summertime Consumption of some meats is also affected by holidays and religious beliefs But the total demand for meat apparently remains about the same throughout the year

The second factor is the basic economic law that price is a function of supply and demand Third if demand doesn t change, *price becomes a function of supply* In the case of meat it might be called a *drastic* function of supply A slight change in supply of meat invariably results in a very drastic change, in the opposite direction in price In the first three months of 1957, compared to the first three months of 1956, there was a four per cent average decrease in meat production in the United States At the same time there was a 16 per cent average increase in the price [1]

Meat consumption doesn t react sharply to slight price changes Demand is rather constant If supply increases a bit prices drop a bit Increased consumption would prevent accumulation of surpluses and price wouldn t slip so low But with meat, consumption *doesn t* increase much, excess supplies accumulate and prices skid

The fourth consideration is that supply (Figure 22 3) is and has been for many years a function of *convenient and economical production* This was previously pointed out in the discussion of feeder cattle and lambs It is likewise true for hogs

22 6 Slaughter Hogs

The traditional farrowing months for hogs are in early spring and in the fall Routine feeding and management make hogs ready for slaughter

[1] Stockman s Letter 10 6 John Morrell & Co Ottumwa Iowa 1957

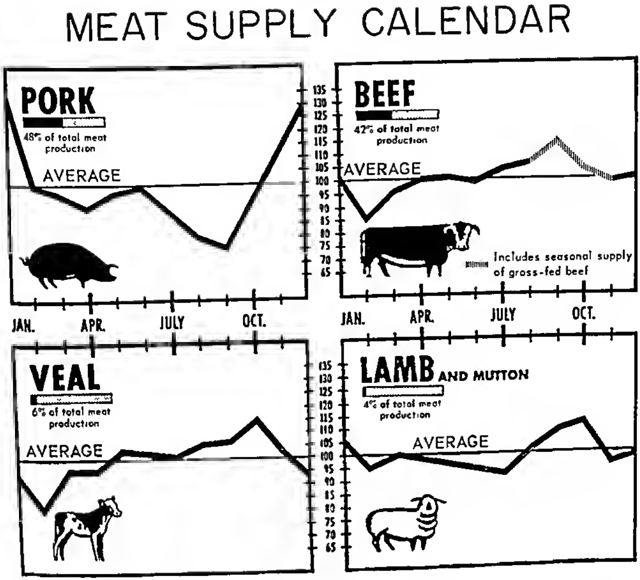
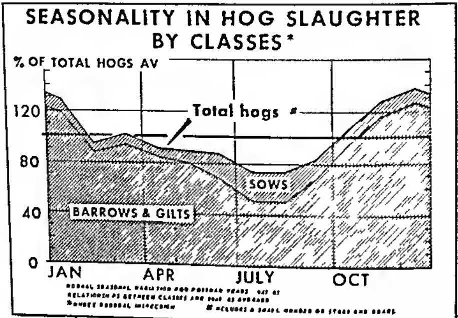


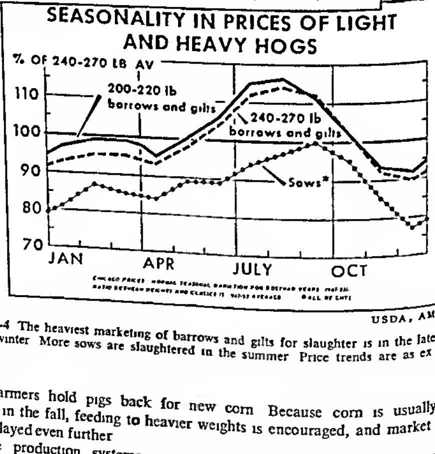
Figure 22-3. Approximate monthly variation in production of each kind of meat for an average year. (American Meat Institute)

at seven to eight months of age. There results, then, a tremendous run of hogs on the markets during November, December, and January, from farrowings that reach a peak in April and May. A slight marketing peak in early spring is caused by hogs farrowed in the fall (Figure 22-4). The peak in the winter is much higher than in the spring due to the natural advantage of spring farrowing. About twice as many sows are farrowed during the spring as in the fall, many hog raisers farrowing only in the spring.

Spring farrowed pigs are marketed later, in relation to farrowing, and are spread over a longer period. This is due to the contrast in management of "spring pigs" and "fall pigs." Fall pigs, usually born in late August or September, are confined to dry lots during most of their growing and finishing period (though some may be used to clean up grain after harvest). The result is relatively *quick and uniform* finishing of fall pigs.

Spring pigs, however, are managed in a wider variety of ways, some *prolonging* the finishing period. On many farms, spring pigs are grown on pasture. A midsummer oat harvest often means cheap oats which may be fed—a good feed but high in fiber so producing slower gains. In addition





USDA, AM

Figure 22-4 The heaviest marketing of barrows and gilts for slaughter is in the late fall and winter More sows are slaughtered in the summer Price trends are as ex pected

many farmers hold pigs back for new corn Because corn is usually cheaper in the fall, feeding to heavier weights is encouraged, and market ing is delayed even further

These production systems contrast markedly with the systems of "continuous farrowing–confinement–rapid growth" which many hog raisers use But in a study of supply and price cycles it becomes obvious that supply cycles are established by *all* animals, not only by those raised in a particular system

Trends since World War II have been toward continuous farrowing and rapid finishing of hogs. This has caused a noticeable leveling of the seasonal supply cycle. This trend will no doubt continue, though there will still be an advantage for seasonal farrowing on farms with limited housing and equipment.

Another apparent trend is the gradual shift to *earlier* farrowing by those who continue to farrow once or twice each year. This has been made possible with better housing and equipment and has been encouraged by the possibility of higher prices for hogs marketed before supply peaks occur.

Why are so many sows slaughtered in the summer? The main reason is that sows are usually sold after they wean their second litter.

22.7 Slaughter Sheep and Lambs

Figure 22-5 shows an average seasonal slaughter cycle for sheep and lambs, as well as price fluctuations for lambs. Note the extreme peak in the fall at the end of the grazing season. This is evidence that a large proportion of lambs, as well as most cull ewes, are sold for slaughter directly off grass.

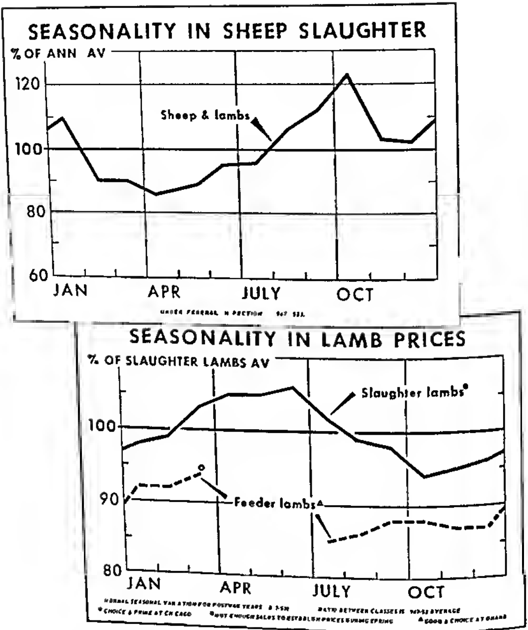
There are two major groups of slaughter lambs—grass lambs and fed lambs. Lambs from farm flocks of the Midwest are usually finished on grass, though a few may have been creep-fed grain. Some years many western lambs are also finished enough for slaughter when they come off grass in the fall.

There are exceptions. Some Midwest flock owners lamb early, creep-feed their lambs, and market early. In the South many lambs are born in the winter and raised on temporary pasture for spring slaughter. The advantages of these two mentioned exceptions are obvious—higher prices (Figure 22-5) and marketing before hot weather. But it is reemphasized that *cycles are set* by *all* lambs.

The second major group of slaughter lambs—fed lambs—are the lambs that were, in most cases, sold as feeders in the fall in dry lot or on wheat pasture for about three months. This group keeps the supply cycle high in December and causes the small peak in January.

Why does the price cycle for slaughter lambs fluctuate less than the supply cycle, in Figure 22-5? First, the supply curve is plotted for *all* animals slaughtered under federal inspection; prices are for *only choice and prime lambs.* Also, since lamb and mutton represent a *small proportion* of total meat supply, slaughter lamb prices are probably greatly influenced by supplies and prices of beef and pork, or even of chicken and turkey.

Supply cycles of slaughter sheep and lambs will likely remain relatively unchanged. Though commercial lamb feed lots are increasing and this will level off the supply slightly, lambs are most economically produced on



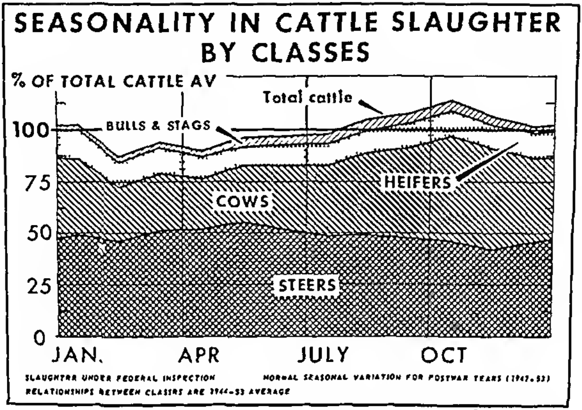
USDA, AMS

Figure 22 5 Seasonal slaughter of sheep and seasonal price trends for slaughter lambs and feeder lambs

grass on open range, where seasonal weather extremes control production patterns This contrasts with hogs, adapted to harvested concentrates and adaptable to confinement rearing

22 8 Slaughter Cattle

Seasonality in cattle slaughter is shown by classes in Figure 22-6 Most beef cows, culled from herds, are sold at the end of the grazing season after calves are weaned Dairy cows are culled all seasons of the year as are those beef cows culled because they had not conceived



USDA, AMB

Figure 22-6. Seasonality in cattle slaughter by classes.

Though not shown here, calf slaughter is also highest in the fall. In many sections of the country where average quality, light weight beef is preferred (Section 25.4), many calves are slaughtered at or soon after weaning. Most are of mixed or dual-purpose breeding and their dams are good milk producers, so they carry sufficient finish at weaning time. Since calves do not have the desirable conformation to demand high prices as feeders, they sell better for slaughter.

Most of the steers and many of the heifers comprising the cycles in Figure 22-6 are sold for slaughter after some feeding in dry lot. Though most are purchased as feeders during the fall, length of feeding period varies greatly. Lower quality feeders, especially those of heavier weights, are fed only 60 to 90 days. Lighter cattle of the lower grades are fed longer on a high roughage program.

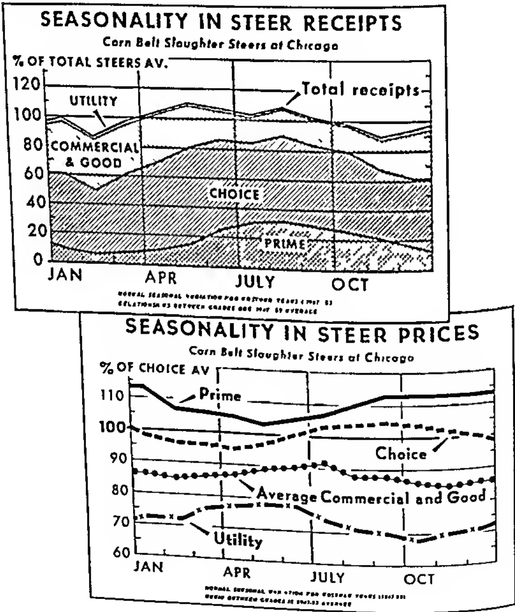
Choice slaughter cattle—from better quality feeders, fed longer, on the average—reach a slight peak in May. Because of the variety of cattle raising and feeding programs, however, choice cattle are marketed the year around. Some, for example, are fed grain once or twice a day while grazing, for cheaper gains. Others are fed silage or other roughage for a considerable period before being shifted to a high grain ration.

Prime cattle, resulting only from quality feeders, fed a long time—six months to a year—on a high grain ration, reach their peak in the summer.

Supply cycles for different classes and grades of slaughter cattle will

vary greatly among markets Chicago handles mostly fed cattle from Illinois, Iowa, and other Corn Belt States, so choice and prime cattle comprise a majority and greatly influence the total supply cycle there (Figure 22-7) Southern markets handle many fat calves and grass cattle The Missouri river markets also handle quite a few grass cattle, as well as some fed cattle from the western Corn Belt

Figure 22-7. Seasonal marketings and price cycles of slaughter cattle, by grade Peaks in marketings of the various grades generally correspond to the popular feeding programs



USDA, AHS

Because of the great range in price level and because the demand for each grade of beef is rather distinct, price cycles for the grades are presented separately. Note that the greatest *range* in price between the high and low grades is in the fall when *total supply* of beef and other meats is highest. (This situation is not peculiar to meat. With most commodities, low quality merchandise suffers most in price when the total supply is high.)

Lower grades, which may include many animals of dairy breeding, sell relatively better in the spring and summer when there is a lower beef supply. A contributing factor to higher prices for low quality cattle in the spring is that farmers with grass are competing with packers for these cattle.

Increases in year-round feeding operations may tend to flatten the supply curve of slaughter cattle somewhat. Increased beef numbers in the South since World War II, as well as possible production of feeder calves in certain feeding areas, may also tend to level out the supply.

22.9 The Weekly Cycle

At the terminal livestock markets most livestock is sold the first part of the week. Studies[2] have shown the trend is most marked among slaughter cattle, feeder cattle, and slaughter hogs, in that order (Figure 22-8). Similar trends exist for sheep.

Some terminal markets handle 40 to 60 per cent of their weekly slaughter cattle receipts and 40 to 50 per cent of the hogs on Mondays. Few markets have a relatively uniform distribution through the week.

Inefficiencies resulting from this situation are obvious. Facilities must be large enough to handle the Monday volume. Many pens stand empty the remainder of the week; unloading docks and scales are unused. Labor to unload, move, feed, and weigh livestock must be hired to handle the heavy market days, and may not be kept busy the rest of the week.

Why does this unique marketing pattern exist? Though slaughter is almost uniform, Monday through Friday, in cities where terminal markets are located, most people cite "more active buyer activity" as the reason feeders *ship* their livestock for the Monday, Tuesday, or Wednesday market. This may or may not be the *real* reason. Obviously packers will buy more livestock earlier in the week if more is present and they know from experience that little will be available on Thursday or Friday. Packers do not want to hold large numbers over the weekend, except as needed for Monday morning slaughter. But often they must buy their Monday supply "in the country," from farmers or at auctions on Friday and Saturday, because of low Friday receipts at the terminal markets.

More livestock feeders, too, will likely be on the market early in the

[2] *Missouri Agr. Exp. Sta. Bull. 712.*

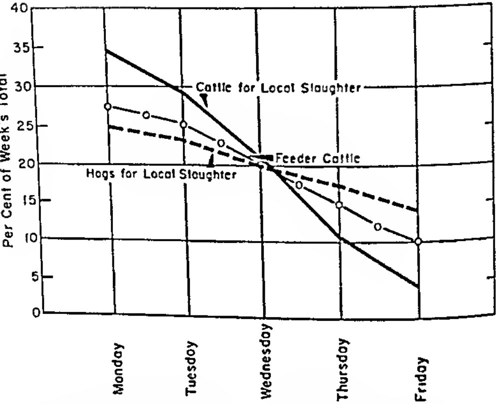


Figure 22 8 Distribution by percentage of cattle and hog receipts at 19 markets for 1954 or 1955 (Adapted from *Missouri Agr Exp Sta Bull 712*)

week looking for feeder cattle and lambs if they know more will be available to choose from

Perhaps a *basic* reason for this uneven weekly cycle in terminal market activity is habit or tradition, of historical origin At one time there may have been a real reason for early week marketing Before refrigeration, which allows holding meat over weekends in packing houses or retail stores, and before modern transportation, which now allows purchased livestock to be shipped to distant packers, packers were probably forced to buy on Monday, Tuesday, or Wednesday, so meat could be locally slaughtered and distributed to consumers before Saturday night

During development of refrigeration and modern transportation, which was *gradual* heavy marketing early in the week continued Perhaps in some cases the situation 'snowballed,' becoming more extreme More buyers encourage more shipments More shipments encourage more buying Terminal market people, as well as truckers and others who are in some way associated with markets, would like to even out this weekly marketing cycle Evening out the weekly cycle will be difficult In what direction do you roll a snowball to reduce its size?

23

APPRAISING SLAUGHTER LIVESTOCK

Most livestock is sold for slaughter on a "live" basis. Packer buyers estimate dressing per cent, carcass grade, and other quality characteristics, then offer a bid per 100 pounds of live weight *(Figure 23-1)*. *Accurate appraisal depends on the appraiser's* knowledge of factors which influence carcass merit—finish, age, weight, degree of meatiness, bruises or injuries, and health—and the *degree* to which each influences merit. Appraisers (packer buyers or sellers) must also know the value of by-products such as wool, hide, and viscera. Though much is yet to be learned, considerable is known about the factors which do influence carcass merit; much of this chapter is devoted to the topic. By-product values vary considerably, so will be discussed only in general terms.

Buyers and sellers must also have the ability to appraise the above items on a live animal, as well as to estimate dressing per cent. Dressing per cent is carcass weight as a percentage of live weight, (carcass wt. ÷ live wt.) x 100.

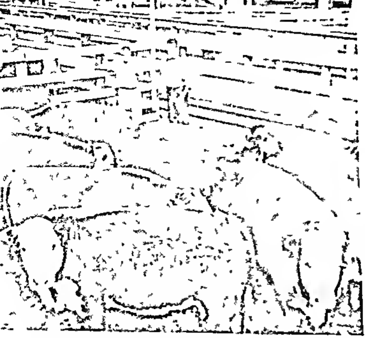


Figure 23-1. Both the commission salesman and the packer buyer, at a terminal market, must be able to accurately appraise slaughter livestock. The buyer, on the right, carries a two-way radio to keep in touch with his "head buyer" and other buyers representing his firm, a major packer. (Omaha Livestock Exchange)

ship or a positive relationship between age and tenderness,[1] at least up to two and a half or three years of age. Older cattle normally carry more internal finish (marbling) which may enhance tenderness somewhat, but age *per se* is not usually a major influence.

Tenderness is inherited to a degree (Table 15-1). Perhaps tenderness increases with age in certain lines, breeds, or species, but decreases with age in others. Little information is available on the influence of age on pork or lamb tenderness.

Meat from older animals—cow beef, mutton, and pork from older hogs—usually has a more distinct flavor. Veal, young spring lamb, and roasting pigs have a relatively mild flavor.

Amount of flavor preferred by consumers varies greatly and is usually not a basis for discriminating against older or younger animals in slaughter livestock appraisal, except in the case of sheep and lambs. The flavor of lamb is unique and slightly stronger than beef or pork. Therefore, many consumers purchase only young lamb because they do not care for the stronger "mutton" flavor that comes with advanced age in yearlings and ewes. There is a rather severe price discrimination on yearlings and ewes, compared to lambs.

Older animals carry more finish, unless they have been on a limited ration, so the meat is usually juicier and more palatable. As the percentage of fat in the carcass increases, the percentage of moisture declines. This means that less weight is lost during cooking.

USDA grade specifications favor younger animals. Older animals grade lower when finish and other quality traits are similar. Lighter and younger animals grade high with less finish. Carcasses from older animals have

[1] R. M. Alsmeyer *et al*, *Am Meat Inst Found Circ 50*, p 85, 1959.

larger, harder, whiter bones, and usually a darker colored lean. Muscle fibers are more coarse.

Though some consumers prefer lighter colored lean, the effect of color on flavor and palatability is not fully known.

It must be recognized that USDA grades are simply a rough categorization of carcass quality. As more is learned about the above traits and their influence on quality, the grade specifications can be revised.

23.2 Influence of Weight

Since weight is highly correlated with age, topics discussed in the previous section apply here.

Weight is associated with degree of finish in hogs because they are generally full fed a high energy ration and tend to fatten early in life. The weight of fat increases faster than the weight of lean after the pig weighs about 50 pounds.[2] Therefore weight is of great concern to a packer in appraising carcass merit of hogs (see also Table 9-1, page 140). It is also important to the producer, since high energy rations are expensive and more feed is required per pound of gain on heavier, fatter animals.

Because sheep and cattle are raised and finished on widely varied feeding programs using rations differing greatly in energy level, weight of these animals is not so highly correlated with meatiness and carcass merit.

Even with sheep and cattle, however, weight is important to the packer buyer because of consumer desire for cuts in certain weight groups. Housewives generally prefer small, light weight cuts of beef, pork, and lamb, except in the case of chops or steaks. The degree of preference naturally varies among species, among grades, and in different sections of the country. Restaurants, hotels, and institutions often prefer heavier cuts. They serve large groups, and heavier cuts usually shrink less during cooking, because of less surface per unit weight, yielding more servings per pound of meat purchased.

23.3 Influence of Sex

Sex is of little importance in appraising slaughter livestock except as it might, in the case of pregnancy, influence dressing per cent. Hogs are normally slaughtered at five months of age, when there is little chance of gilts having been bred. Also gilts and barrows are normally fed as a group and droves of hogs being appraised for slaughter normally contain a persistent 40 to 45 per cent gilts and 55 to 60 per cent barrows. Barrows normally carry about a tenth of an inch more backfat, and proportionally less lean.[3]

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[2] S. E. Zobrisky *et al.*, *Missouri Agr. Exp. Sta. Res. Bull. 672*, 1958.
[3] *Ibid.*

A similar situation exists for slaughter lambs, except that droves normally have relatively fewer ewes (More must be saved for breeding than in the case of hogs) There is little difference in finish or other carcass traits of ewe and wether lambs Ram lambs are often discounted $1 00 or more per cwt. at slaughter time, though substantial reasons for this in terms of carcass quality are not apparent when such rams are sold at four to six months of age Carcasses from older rams and ewes, of course, have a stronger, less desirable flavor so are heavily discounted Such carcasses are not normally sold through regular retail channels, but rather are boned out and mixed with other meats for use in 'prepared' meat items

Slaughter heifers often sell for $1 50 to $3 00 less per cwt than steers of similar weight and finish The price differential is usually larger in older and heavier animals, where heifers are more likely to be pregnant There is no apparent difference in carcass *quality*, the main difference is in dressing per cent, and the carcasses may yield slightly lower percentages of trimmed primal cuts

A surprisingly large percentage of heifers slaughtered are pregnant, and dressing per cent is greatly lowered Even in nonpregnant heifers the dressing per cent may be slightly lower, apparently because of a slightly thicker hide and greater weight of the reproductive organs

Steers are normally marketed separately from heifers because of their different rates of growth and finishing (Chapter 8) even though they may have been fed together Therefore a price differential *can* be made It is apparent that a group of open (nonpregnant) heifers may be too greatly discounted in price by a packer buyer, simply because he *assumes* that some are pregnant

The fact that feeder heifers normally sell for less than feeder steers (Chapter 8) is partly a reflection of the price differential at slaughter time, but also may be due to the tendency of heifers to gain more slowly in the feed lot

23 4 Finish

Fat which is finely dispersed through the meat is called marbling (Figure 23 2) It contributes to palatability and desirability—juiciness, flavor, appearance, and perhaps, tenderness

Juiciness is probably the most important single quality factor contributed by marbling It apparently makes meat more desirable by providing lubrication for chewing and, by being in liquid form in meat that is hot, carrying the flavors quickly to sensitive taste buds Fat on the *outside* of a meat cut helps prevent weight loss during cooking and also contributes to the juiciness of cooked meat Extreme quantities of external fat, though, are not necessarily desirable

Meat flavor components have not been fully identified, but it is probable

Figure 23-2. A contrast in marbling The steaks on the left have much more marbling, which is finely dispersed This gives more juiciness to every bite (Iowa State University)

that fatty acids or other compounds carried in the fat contribute directly to meat flavor.

Appearance of meat cuts is influenced by degree of finish. Those with little marbling, especially pork, are soft and watery. They do not "hold their shape" in display coolers and are generally not appealing to the consumer. After cooking they are dry and, in the case of roasts, tend to fall apart, making carving difficult. Cuts with too much fat are likewise undesirable to the consumer.

Though the direct effect of marbling on meat tenderness, as measured by mechanical devices, may be slight, those who eat meat with considerable marbling *think* it is more tender. This is probably because it is juicier and generally more palatable.

Though much is yet to be learned about the value of fat in meat, consumers have long demonstrated their preference for meat that has *some*, but *not too much*, finish. They want considerable marbling, but a minimum of outside finish.

The amount of marbling in meat is not easily appraised by looking at a carcass or feeling the finish on a live animal Generally, but not always, animals with more external fat carry more marbling within the meat. Correlations between external finish and marbling are usually between 0.40 and 0.60.

Even so, until more accurate techniques are developed and tested, feel and visual appraisal or other methods of measuring external fat must be used as an indicator of marbling. Finish over the back, loin, and rump, as well as over the ribs, can be felt. Since animals normally fatten first over

the back and fore ribs, the feel over the loin, rump, and rear ribs often discloses the degree of fattening which has occurred

Well finished lambs have a thick, fat tail In steers the brisket gets heavy and that portion of the scrotum remaining after castration fills with fat. Cattle and lambs with considerable finish walk with some difficulty, swing ing a bit from side to side as fat rolls in front of the flanks, rather than with a clean free and-easy stride

Amount of fat is inversely related to amount of lean, techniques for measuring relative quantities of the two kinds of tissues are presented in Section 23 5

23 5 Meatiness

Regardless of species, the goal in meat animal production is a carcass that contains a high proportion of good quality *lean*, or *muscle* It is certainly desirable to have some degree of marbling within the muscle, as indicated in the previous section, but excess quantities of external fat or heavy seams of fat between muscle groups are definitely not desired. Therefore a major task in evaluating slaughter livestock is to appraise meatiness—the proportion of lean meat (Figure 23-3) It has been widely and repeatedly demonstrated that there is much range in meatiness within *every species*

There are only three major kinds of tissue in pork, lamb, and beef carcasses—lean, fat, and bone If there is more lean, there must be less fat and/or bone Several studies have indicated that the proportions of lean and bone are highly correlated In other words, animals with a higher proportion of lean also have a heavier skeleton, and relatively less fat.

The live probe (Section 16 8) is generally more accurate in predicting the percentage of lean cuts or total lean in pork carcasses than any other measurement that can be taken readily on a live hog. It is certainly more accurate than any visual scoring or appraisal system which has been used, though considerable skill in estimating backfat thickness or percentage of lean cuts can be developed

The probe was first used to appraise meatiness in slaughter hogs, and because of its accuracy, is also used for appraising meatiness of prospec tive breeding gilts and boars The probe measurement of backfat thickness on live hogs is as accurate as or more accurate than, backfat measure ments taken on a carcass as an indicator of the percentage of lean Cor relations of live probe and other measurements with certain carcass traits are given in Table 23 1

Figure 16-6 (page 230) illustrates why the probe is not so valuable as an indicator of meatiness in cattle and sheep The irregularities of the eye muscle circumference prevent accurate measurements

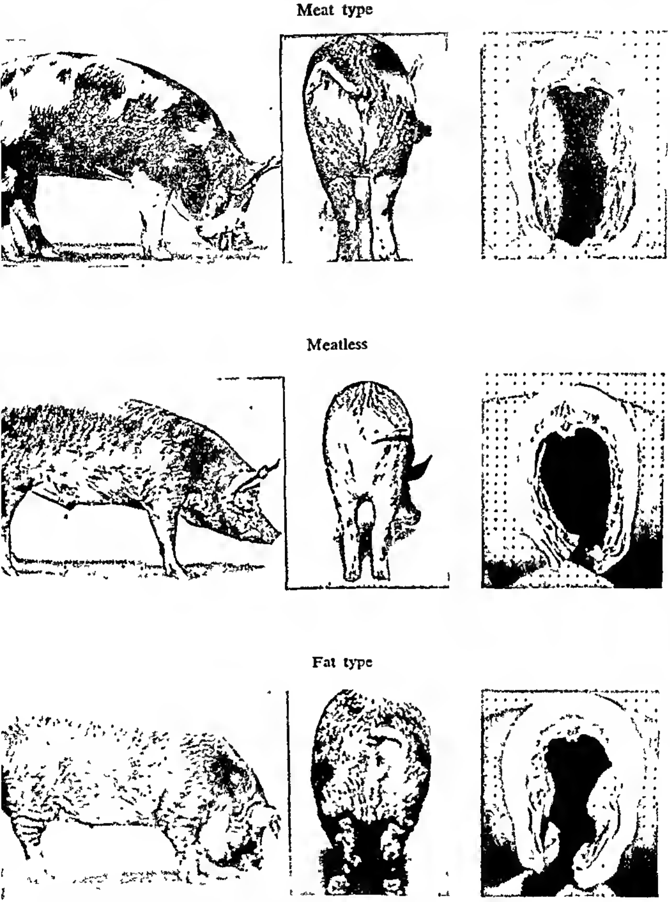


Figure 23-3. "Meat type," "meatless," and "fat type" market hogs. Pictures on the right are cross-sections of the carcasses at the tenth rib. (Geo. A. Hormel & Co. and National Swine Growers Council)

Table 23-1. Correlations Between Certain Live Animal or Carcass Measurements and Carcass Traits*

Measurement	x	Carcass traits	Hogs	Cattle	Sheep
Live probe	x	Per cent lean cuts	-0.67		
		Per cent primal cuts	-0.61		
		Fat trim	0.67		
		Carcass backfat	0.81		
Carcass backfat	x	Total lean	-0.63		
		Yield of primal cuts	-0.58		
		Total fat	0.79		
		Fat content of ham	0.66		
		Fat content of picnic	0.53		
		Fat content of edible meat	0.84		
		Fat content of carcass	0.95		
Carcass specific gravity	x	Per cent lean cuts	0.86		
		Per cent fat cuts	-0.81		
		Per cent body fat		-0.96	
Carcass length	x	Per cent lean cuts	0.02		
		Yield of primal cuts	0.01		
Planimeter area of loin eye	x	Total lean	0.68		
Length of loin eye x width	x	Total lean	0.60		
Per cent defatted ham	x	Per cent lean cuts	0.89		

*W J Aunan and L M Winters, *J Animal Sci* 8 182, 1949, O G Hankins, USDA *Cir 731*, 1945, C P McMeekan *J Agr Sci* 31 1 1941, L N Hazel and E A Kline, *J Animal Sci* 11 313, 1952, J V Whiteman *et al* *J Animal Sci* 12 860 1953, H F Kraybill *et al*, *J Applied Physiol* 3 681, 1951, J N Cummings and L M Winters, *Minneapolis Agr Exp Sta Bull 195*, 1951, 32, C J Brown *et al*, *J Animal Sci* 10 97, 1951, A M Pearson *et al*, *J Animal Sci* 16 481, 1957, J R Price, *et al*, *J Animal Sci* 16 85, 1957, and Charles Smith *et al*, *J Animal Sci* 16 1072, 1957

A flaw detector, which emits sound waves and measures the time it takes for them to bounce back from junctions between tissues, can be used to measure fat thickness and meatiness. It was also mentioned in Section 16 8. Such an instrument may be more adapted to assembly line use, in appraising carcasses in a plant, or hogs in an alleyway, than the carcass backfat measurement or live probe, and much more accurate than visual grading

It is apparent that measurements which might be used to appraise carcass traits have been more deeply studied for pork than for beef or lamb. There are several reasons First, carcass quality of pork has been of great economic concern since World War II. Consumers have clearly demanded leaner pork Processors, then, have had the task of appraising the meatiness of slaughter hogs or carcasses of hogs purchased on a "grade and yield" basis It was necessary to develop appraisal techniques that were rapid, simple, low cost, and accurate

The second reason is that research findings could be applied to almost all hogs sold for slaughter Most barrows and gilts are slaughtered between 200 and 230 pounds, whereas cattle sold for slaughter commonly range

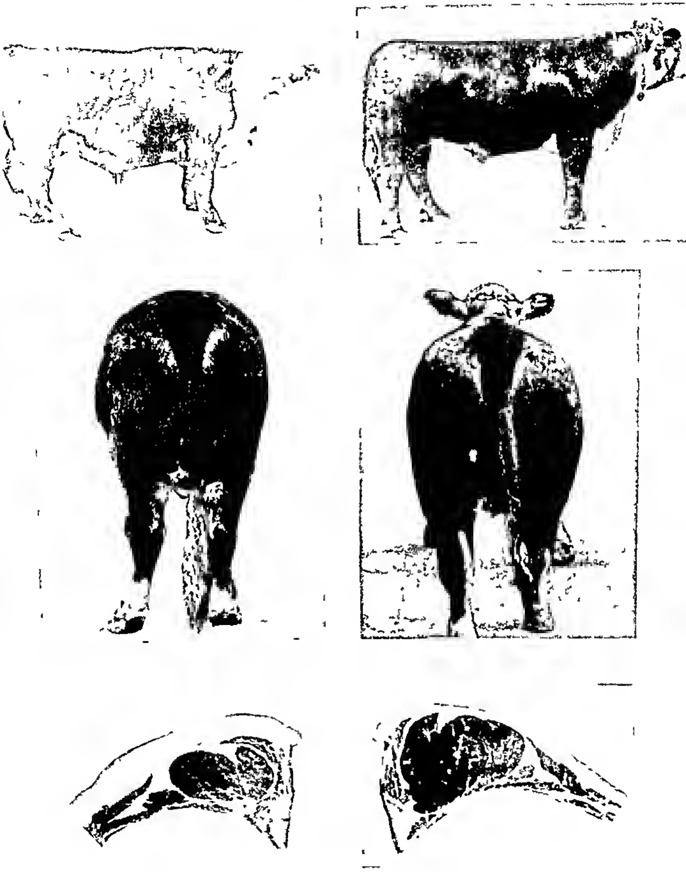


Figure 23-4. Two "U.S. Choice" steers of the same weight with great contrast in muscling The steaks are cut from the *last* rib. Based on cuts *yielded*, the steer on the right had eight percentage units more boneless primal cuts and was worth $73.65 more to the retailer. Note that this steer has thicker muscling over the back, more bulging rounds, and a trimmer brisket and underline. (Livestock Division, AMS, USDA)

from 400 pounds to over 1100 pounds Techniques developed for appraising carcass quality in heavy cattle may not be equally valuable for appraising light cattle

Though less research has been done on techniques for appraising meatiness in slaughter cattle or sheep, it is reasonable that the same principles apply to them as to hogs Animals that carry more fat have less lean and/or less bone If techniques were developed, Table 23-1 probably could be completed for cattle and sheep, with correlations of about the same size, at least within market weight groups

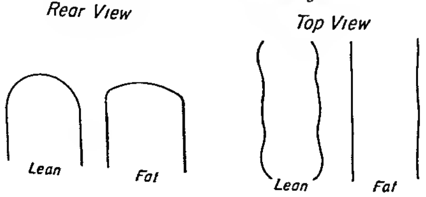
Variations in relative meatiness among beef carcasses of the same grade are very apparent Many retailers personally select their own carcasses, they are able to choose those which will "cut out" the highest proportion of meaty cuts (Figure 23 4) The grading of beef carcasses according to meatiness, as well as finish, was mentioned in Section 21 7

Though the probe and other measuring techniques are emphasized as being extremely accurate in appraising meatiness, people also can develop real skill and accuracy, if they are observing gain much experience, and always *compare* their appraisal with some *objective and accurate measurements* such as live probe, backfat thickness, or percentage of lean cuts Without such comparison they might gain *confidence, but not accuracy*

Visual appraisal of leanness in hogs should include observation of the jowl, underline, ham, tailhead, and other points Review Figures 23-3 and 23 4 In lean hogs the jowl is trim and solid, not heavy, soft, and loose The underline and side should be trim and smooth, heavy creases and wrinkles should not appear as the animal walks The ham is usually somewhat tapered at the base, not necessarily deep and full The tailhead is usually prominent on a lean hog, similar to that on a heavily muscled horse The tailhead of an extremely fat hog usually appears counter sunk, like the stem of an apple, surrounded by a roll of fat As viewed from the front or rear, the topline of a lean hog is smoothly arched, that of an extremely fat hog is flat and wide (Figure 23 5)

It is apparent that the loin of a hog must be wide enough for a large, bulging eye muscle on either side of the backbone, yet without excess finish

Figure 23 5 Diagrammatic profiles of lean and fat market hogs



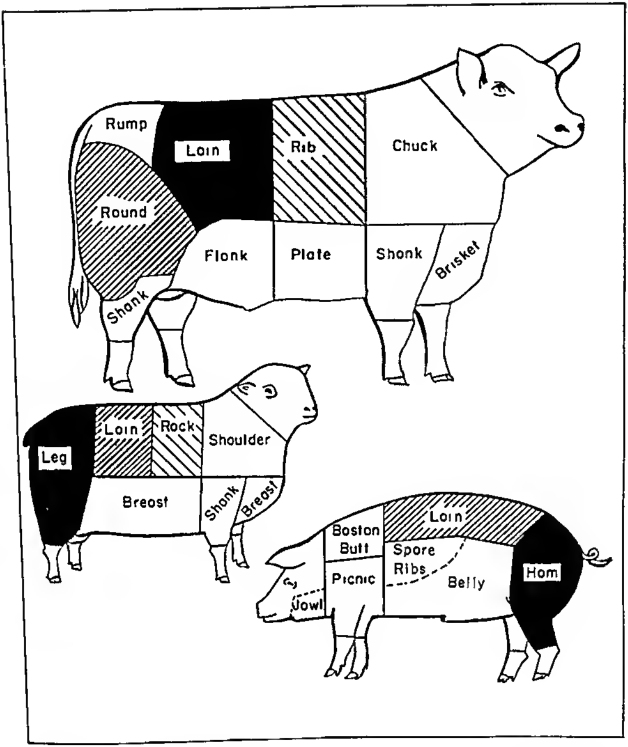


Figure 23-6. Normal wholesale cuts of beef, pork and lamb. Darker shading indicates higher total value (weight × price).

Other observations can improve accuracy in predicting meatiness, regardless of species. Especially meaty (muscular) animals are not necessarily uniform in width. Their shoulder and hind leg (round, leg, or ham) should be *bulging* and show evidence of muscling. They should be wider in the shoulder than immediately behind the shoulder, and wider at the hind leg than immediately in front of the leg. It is worthwhile to review typical muscle patterns in an animal anatomy book. Such a review demonstrates that animals extremely uniform in width are not necessarily meaty—they just have fat where there normally is muscle.

Muscling is especially noticeable as the animals walk. Muscle movements are not hidden by thick layers of fat, if the animal is meaty

Proportion of high priced cuts is given much consideration in appraisal of slaughter animals The hindquarter and the rib area, yielding mostly steaks, chops, and the better roasts, is most valuable in carcasses of all species Figure 23-6 indicates the approximate relative value of the wholesale cuts (see also Table 24-1, page 349)

It is apparent that high priced cuts are those with a higher proportion of lean and with most muscles within the cut running in the same general direction This makes cooking, carving, and eating easier and simpler These cuts also carry muscles which are normally more tender In locker plants and other retail outlets, the hindquarter normally sells for about 20 per cent more per pound than the forequarter

The range in proportion of wholesale cuts of fore- to hindquarters among carcasses of the same grade may be surprising In one group of 56 USDA Choice heifer carcasses selected at random,[4] the lower one third averaged but 47 27 per cent of their weight in hindquarter while the top one third averaged 52 71 per cent

23 6 Grade

USDA carcass grade and specifications, as well as private grading systems, were discussed in Chapter 22 Grades are recognized as a rough grouping of carcasses according to merit, considering both proportions of cuts and relative quality of the meat The purpose of this section is to discuss the accuracy with which carcass grades of live animals can be estimated

Table 23-2 summarizes the accuracy of experienced packer buyers in estimating USDA grade of individual calves, cattle, and lambs The average error is much larger than would be expected if grade had been estimated on groups, or lots, of livestock Individual errors in appraisal would tend to cancel out each other, to some degree, in group appraisal

In these studies there was an obvious tendency for the buyers to overestimate the grade of lower quality and underestimate the grade of higher quality animals There seems to be a basic human tendency to avoid making estimates that are extremely low or high This means, or course, that if animals are priced according to these estimates, sellers of very low quality animals profit, but sellers of high quality animals lose, by live animal appraisal It might be interesting to calculate the average pricing error caused by these estimation errors, using current carcass prices

In a similar study the accuracy of 16 packer buyers in estimating carcass grade of individual market hogs and groups of hogs was surveyed

[4] Rath Packing Co private communication, 1959

Table 23-2. Accuracy of Packer Buyers in Estimating Carcass Grade*

Deviations from USDA grades	Per cent of 710 Steers & heifers Kans. & Minn.[1]	390 Cows, Ky. & Minn.	613 Veal calves Wisc.	406 Veal calves, Ky.	319 Lambs, Ky.	444 Lambs, S. Dakota	Deviations from USDA grades
+ 2	0.2	0.8	3.7	1.0	1.9	2.5 0.9	+ 2 + 1 2/3
+ 1	16.2	13.6	28.4	19.0	32.3	4.0 10.4 18.4	+1 1/3 + 1 + 2/3
0	67.2	61.8	52.6	62.0	59.9	20.5 19.1 13.5	+ 1/3 0 - 1/3
- 1	16.2	18.7	13.7	17.0	5.9	5.9 4.0 0.8	- 2/3 - 1 - 1 1/3
- 2	0.2	5.1	1.8	1.0	—	—	- 1 2/3 - 2
Av. error (fraction of grade)	0.38	0.44	0.48	0.35	0.42	0.55	

*Adapted from *Purdue University Agr Exp Sta Bull. 611*, October 1954.
[1]Estimated from data provided.

Results are given in Table 23-3 for the five highest and five lowest. The next to last column of the table shows improvement in appraisal accuracy achieved when grades are estimated on a group rather than on individual hogs.

Table 23-3. Accuracy of Estimating Carcass Grades on Live Hogs*

Buyer	Hogs graded individually: No.	Hogs graded individually: percentage accuracy	Hogs graded in groups: No. groups	Hogs graded in groups: percentage accuracy	Difference in percentage accuracy	Years buying experience
A	50	76.0	2	98.0	22.0	9.0
C	100	62.0	4	84.0	22.0	3.5
D	149	51.6	6	77.4	25.8	6.0
E	171	55.2	5	93.1	37.9	5.0
G	53	60.4	6	81.1	20.7	16.0
P	123	49.0	5	83.7	34.7	0.6
S	151	55.3	6	76.6	21.3	0.5
T	159	58.2	6	76.4	18.2	3.0
U	100	46.9	4	75.5	28.6	2.0
V	151	34.5	6	52.7	18.2	20.0
Av.	128	54.0	4.8	80.1	26.1	9.9

*Adapted from *Purdue University Agr. Exp. Sta. Bull. SB 650*, 1957.

Estimates made for groups of hogs were more accurate Those graders who had experience appraising *carcasses* tended to do a better job estimating grades on live hogs The correlation between years of experience and accuracy of appraisal was low

It is apparent from Table 23 3 that there is considerable range in the ability of buyers to appraise carcass grade on live animals Pricing accuracy consequently may be poor when slaughter animals are sold on a "live" basis

It is emphasized that this discussion should *not* be interpreted as a recommendation for selling on a carcass grade basis Certainly many other factors must be considered, in addition to appraisal of live animals The interpretation of this discussion should be that live animals *can be* appraised relatively accurately by *some* buyers

23 7 Dressing Per Cent (Yield)

Dressing per cent of animals has no influence on the merit of the carcass but is important in appraisal of live slaughter animals Packer buyers are familiar with market value of carcasses, but need to calculate the value of the live animal per cwt in order to make a bid If a buyer overestimates dressing per cent of a 1000 pound steer by one percentage unit, the animal will yield 10 pounds less carcass than he presumed If the carcass is worth $40 per cwt, the animal yields $4 less carcass value Obviously, then, accurate estimation of dressing per cent is important.

Approximate dressing per cent values for various classes and grades of slaughter livestock are given in Table 23-4

Table 23-4 Approximate Dressing Per Cents of Livestock

Hogs		Cattle		Sheep	
Average	70	Average	60	Average	50
Barrows & gilts		Steers & heifers		Choice lambs	50
U S No 1	69	Choice & prime	63	Good lambs	50
U S No 2	70	Standard & good	60	Fat ewes	51
U S No 3	72	Commercial	56	Thin ewes	46
Medium & cull	67	Cows			
Sows	68 72	Utility cutter, and canner	52		

What factors influence dressing per cent? Conformation and finish of the carcass have some effect Animals that are more symmetrical and blocky usually dress higher, fatter animals dress higher, too, perhaps for the same reason Thin, long legged, long necked, angular animals, such as utility cows, dress very low

A major influence on dressing per cent is the volume of feed and/or water in the digestive tract—"fill Excessive fill lowers dressing per cent markedly, since the carcass then represents a smaller proportion of live weight Thickness and weight of cattle or calf hides, or sheep pelts, in

fluence dressing per cent. Also, a heavy growth of wool means a lower dressing per cent.

Table 23-5 presents a survey of the accuracy of certain packer buyers in estimating dressing per cent of individual calves, cattle, and lambs, and also lots of lambs. As was true in grade estimates (Table 23-2), extremely low dressing animals or groups were generally estimated too high and high dressing animals or groups were estimated too low. Also, there was a tendency to underestimate dressing per cent more often than to overestimate. This might be an expected, cautious thing for a packer buyer to do.

Table 23-5. Accuracy of Packer Buyers in Estimating Dressing Per Cent*

Deviations from actual dressing percentage	710 Steers & heifers, Kans. & Minn.	390 Cows, Ky. & Minn.	613 Veal calves, Wisc.	406 Veal calves, Ky.	306 Lambs, Ky.	27 Lots of lambs, S. Dakota
Total overestimated	23.0	19.8	18.8	28.1	32.5	44.4
+ 7 & above	—	2.3	1.0	1.0	1.3	—
+ 6	—	0.5	0.5	0.5	1.6	—
+ 5	—	1.3	1.8	0.5	1.8	—
+ 4	0.7	2.8	2.4	2.0	4.2	3.7
+ 3	2.3	2.3	3.6	4.7	7.8	7.4
+ 2	7.3	4.4	3.5	6.6	6.2	16.5
+ 1	12.7	6.4	6.0	12.8	9.8	14.8
0 ± .5	30.4	13.3	11.7	21.7	11.1	33.3
- 1	18.7	11.8	11.7	18.7	12.1	7.4
- 2	14.5	10.3	11.4	9.4	11.4	—
- 3	8.5	10.5	13.1	9.4	8.5	3.7
- 4	2.8	9.7	10.4	5.4	10.4	7.4
- 5	1.4	8.2	8.5	4.4	4.2	3.7
- 6	0.4	6.9	5.5	1.7	4.9	—
- 7	0.3	3.3	3.9	—	1.6	—
- 8 & below	—	6.2	4.0	1.2	3.3	—
Total underestimated	46.6	66.9	69.5	50.2	56.4	22.2
Average error (percentage units)	1.5%	3.3%	3.2%	1.9%	2.83%	1.55%

*Adapted from *Purdue University Agr. Exp. Sta. Bull 611*, 1954.

Dressing per cent is important in appraisal of slaughter hogs, but may not be emphasized so much as in cattle or sheep. One reason is that there is less variation caused by differences in content of the digestive tract, the pig being a non-ruminant. The second reason is that extremely fat hogs, which *grade lower, dress higher.* But when live bids are calculated on the basis of an estimated dressing per cent, it is just as important that this estimate be accurate.

23.8 By-Products

By products represent a rather large portion of the value of slaughter sheep, cattle, and calves (Table 23 6) There is considerable variation in by product value from season to season or from year to year, but percentages given in the table for noncarcass by products are reasonable averages Certain portions of the *carcass* such as some bones, kidneys, and ligaments, may also be defined as by products (Section 24 11)

Table 23-6 Approximate Relative Value of Carcasses and By Products

	Carcass (including fat trim)	Hide or pelt	Other by products
Lambs	75%	15 2%	9 8%
Calves	78 0	13 6	8 4
Cattle	85 0	6 4	8 6
Hogs	95.0		5 0

In the case of calves, cattle, and hogs, the value of by products does not vary greatly among animals or groups of animals, except where cattle hides might be damaged by brands or grubs The value of wool carried by sheep and lambs may vary greatly, however, depending on age, wool growth, and wool quality A further discussion of the variety of by products yielded in livestock slaughter is given in Section 24 11

23.9 Injuries

Bruises on slaughter livestock are costly Losses as high as $50,000,000 per year for the livestock industry, because of injuries incurred during handling of slaughter livestock, have been estimated.[5] Such figures, though, do not have much impact on producers, truckers, or handlers of stock, even when converted to a per animal basis.

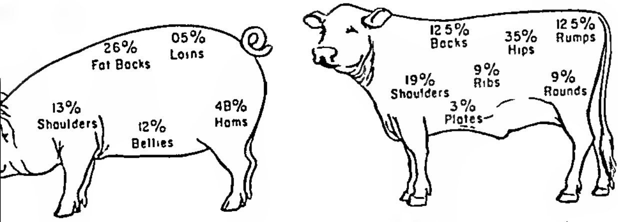
Those who regularly appraise livestock are familiar with situations where bruising is common. In such cases they assume some loss due to bruises and lower their appraisal accordingly Hauling mixed loads—cattle with hogs or sheep—usually causes more bruising on the smaller animals. Loading too tightly or giving a few animals too much room in a truck or railroad car with slick floors will contribute to injury and bruises.

Figure 23-7 illustrates where on the animal most hog and cattle bruises occur Note that most are on the high priced cuts.

Thin cattle bruise more easily, they lack the cushioning layer of fat. There are usually more bruises on carcasses of cattle that carried horns,

[5] *Livestock Conservation Handbook*, Livestock Conservation, Inc., Chicago 1955.

CATION OF HOG BRUISES LOCATION OF CATTLE BRUISES



igure 23-7. Location of hog and cattle bruises. (Livestock Conservation, Inc.)

r that were extremely nervous. Packer buyers note these items; they also ecome acquainted with producers whose livestock often carries bruises. No doubt many bruises are caused by irate producers or handlers of tock, who lack proper facilities for restraining or loading for shipment, and who forget that valuable cuts of meat lie just under the animal's skin.

23.10 Health

Though federal, state, and city meat inspection generally insures that meat sold at retail is free of disease and fit for human consumption, appraisers and buyers of slaughter livestock must be alert to the symptoms of serious illness. When a carcass is condemned in the packing plant because of disease or other reason the loss is suffered by the packer, unless the animal was purchased "subject to inspection."

Though most cattle which have reacted to a tuberculosis test are sold "subject to inspection," tuberculosis accounts for a very small proportion of cattle carcasses condemned. Major causes of condemnation, for all species, are pleurisy or pneumonia, enteritis, emaciation, abscesses, septicemia, and arthritis.[6] Large numbers of hog carcasses are condemned because of cholera, erysipelas, or tuberculosis. Many calves are condemned each year because of immaturity, having been slaughtered at only a few days of age.

23.11 Selling on "Grade and Yield"

Direct marketing of slaughter livestock was discussed at length in Chapter 20, and it was mentioned that this affords opportunity for selling animals on the basis of carcass grades and weights, eliminating the necessity of appraising *live* slaughter animals. Previous sections in this chapter indicate that pricing inaccuracies do exist when slaughter animals are

[6] USDA, Summary of Activities, Meat Inspection Division, 1961.

appraised alive because of errors in estimating yield, grade, meatiness, and other factors

It should be emphasized however, that pricing inaccuracies *are not necessarily eliminated* when slaughter livestock is sold on the basis of grade and yield Carcass grade, whether applied by the packer or a USDA employee, does not always indicate the *true value* of the carcass (Section 23 5) This is because carcass grade is a subjective appraisal and may be applied by men who vary greatly in their ability to grade carcasses according to specifications Also, selling livestock on a grade and/or yield basis implies considerable reliance on the packer to protect the seller's interests —carcasses are usually weighed and graded by packer employees

Methods packers use to buy on grade and yield vary Some include laborious calculations, converting carcass prices to live animal prices The packer may like to show the producer how much he gained or lost by selling on this basis rather than on a live basis

When only yield is considered, the buyer appraises grade on the live animal He then makes a bid based on (1) carcass weight or (2) on live weight according to how the animals will dress out For example, he may offer $25 per cwt for cattle if they have a dressing per cent of 62 per cent, or $25 30 per cwt if they have a dressing per cent of 63 per cent This allows the producer to compare the bid with other live animal bids he may have received Dressing per cent would be calculated at the plant, when live weight and carcass weight are known

When only grade is considered, bids are offered on a live weight basis according to how the carcasses grade When both grade and yield are considered, the above procedures can be combined in a variety of ways

It must be recognized that those who argue the advantages and disadvantages of buying slaughter livestock on grade and/or yield are often concerned more with *where* the animals are being marketed (Figure 23 8) Many packers who buy direct encourage producers to sell on grade and yield since this method of selling is usually not employed at terminal markets or auctions Terminal market personnel, however, including commission salesmen, stockyard company employees, and others, strongly discourage selling on grade and yield They and auction representatives claim such selling eliminates competitive bidding It is emphasized that this chapter is not written to include a consideration of *where* animals are most advantageously marketed Rather, it is restricted to *appraisal* of slaughter animals

In general, producers have found it advantageous to sell high quality, high yielding animals on a carcass grade and/or yield basis, and not profitable to sell low quality, low yielding animals on that basis The reason is that buyers who appraise live animals tend to underestimate the value of the best and overestimate the value of the poorest (Sections 23 6 and 23 7)

Figure 23 8. Most 'interior" packers—those located in feeding areas rather than at terminal markets—buy livestock on grade and yield Price is calculated, according to grade as the cold carcasses are weighed Sellers may also sell on live appraisal, if they wish (The Rath Packing Co)

It has also been observed, however, that cattle carrying considerable dairy breeding are sometimes discounted too heavily by packer buyers when they appraise the animals on a live basis Many of these cattle produce relatively high quality carcasses, having been fed long enough and on a good quality ration In such cases it is advantageous to sell on a carcass grade and weight basis

The feeder who is familiar with the quality of carcasses his animals normally produce can do a better job of deciding the selling method he should use If his breeding stock is of consistent quality and his feeding and management practices uniform, he can predict, with relative accuracy, dressing per cent of his animals and carcass grades

24

PROCESSING MEAT ANIMALS

Section 2.6 discussed the meat packing industry as a part of animal agriculture. This chapter will cover meat processing, from live animals to retail cuts, wieners, and other meat items in the retail counter.

Certain characteristics of the meat processing industry should be pointed out. (1) Processors compete for both purchase of raw materials and sale of finished product. (2) They have little control over quality or quantity of livestock available. (Control may be increasing, see Section 10.8.) (3) Meat is perishable—it must be sold. (4) Since meat is perishable and sold rapidly, there is quick turnover of capital. (5) There are many by-products which bring return. (6) The industry is considered 'essential' because it puts food in usable form. Some of these characteristics may be considered unique to this industry.

There is much range in size of meat packers who operate in the United States. The largest do a national or international business. They have plants in many large cities of the United States, usually near terminal markets, and also in some foreign countries. These companies may also operate other enterprises besides meat processing.

Medium sized packers have fewer plants and usually operate within a certain area of the country. Many have developed in livestock *producing* areas, rather than near terminal markets. Such companies, therefore, buy much of their livestock direct from the producer. Many smaller companies with single plants operate in this same manner, though their operating area may be smaller.

In the first half of the twentieth century there was widely recognized dominance of a few large packers and little evidence of technological progress. Changes have occurred, however, and are continuing. There has been a marked trend toward decentralization of meat processing for a number of years. Volumes of livestock slaughtered in Chicago, eastern cities, and San Francisco have dropped sharply. More plants have been built in livestock producing areas.

Larger companies are doing proportionally less of the business than formerly.[1] The percentage of cattle slaughtered by the four leading firms,

[1] Willard F. Williams. *J. Farm Economics* XL. 315, 1958.

for example, dropped from 54 per cent in 1916 to 31 per cent in 1954. Between 1947 and 1955 the four largest packers decreased from 40.4 per cent to 36.4 per cent of the hogs slaughtered. Packers ranking from fifth to tenth in size, however, increased from 14.6 to 21.2 per cent.

Independent packers (those who operate one or a few plants rather than a national chain) tend to specialize in species or quality of livestock slaughtered. Less than one third handle all three species; more than 20 per cent slaughter only one species. Many handle only certain grades, catering to specific outlets such as supermarkets, or hotels and night clubs.

24.1 Slaughter Procedures

Though procedures vary among species, livestock slaughter always includes bleeding, removing the hair or skin, and removing the viscera—trachea, lungs, esophagus, stomach, intestines, accessory organs, heart, and reproductive organs. The head is also removed, and the "carcass" remains.

Cattle are usually stunned with a cartridge or air-driven "bolt pistol," in plants operating according to federal or state "humane slaughtering" laws, so they are immobile and can be shackled and hoisted into the air for bleeding. Calves are sometimes stunned electrically. In either case, bright lights are often used to blind the animals to the approach of the stunner's hand. Since the animals are only stunned, the heart continues to pump while the animal is bled, forcing out more of the blood. The head is skinned out and removed and the animal is then lowered to the floor or onto a moving skinning table. Shanks are skinned out and removed at the knee and hock, and skinning continues.

Great skill is developed by cattle skinners, to avoid cutting the hide or damaging the appearance of the carcass with the knife. In recent years an electrically operated knife, requiring a less skilled operator, has been developed. Some packers have installed large, complex skinning machines (Figure 24-1). Some work still needs to be done by hand, but the machine does reduce labor costs. The hide of light calves is usually not removed till after the carcass chills.

Beef that is intended for Jewish consumption is slaughtered by the Kosher method. Since a complete bleed is considered most important, the cattle are not even stunned before bleeding. They must be bled under the supervision of a Rabbi or a representative of the Rabbinical Board. Because of further restrictions on beef consumed by Jewish people (Section 25.7, page 367) a large percentage of heavy, high quality beef cattle are slaughtered by the Kosher method.

Humane slaughter of hogs usually involves electrical stunning or immobilization in a carbon dioxide-filled pit. The hogs "pass out" without

Figure 24-1 Mechanical hide puller After shanks and belly are skinned by hand, machine pulls off the hide. (Swift & Co)

Figure 24-2. Immobile hogs are carried up from the carbon dioxide filled pit by conveyor, then bled. (*Meat Magazine*)

oxygen, and are carried out of the pit by conveyor, then bled (Figure 24-2). Immobilization makes the slaughtering procedure quieter, prevents some bruises, and also is safer for the workers. Avoiding excitement prior to slaughter seems to improve pork quality and prolongs shelf life of pork cuts subsequently cured.[2]

Because hogs are so difficult to skin when "hot," only the hair is removed. After bleeding, the hogs are scalded in a vat at about 145° F. for several minutes. This loosens the hair follicles so most hair is easily removed by paddles of the dehairing machine. After dehairing, the carcasses are hung from a rail for the remaining steps. The few small hairs not removed by machine are usually burned off as the carcasses pass through a gas flame. The head is then removed before evisceration.

After immobilization, sheep and lambs are usually hoisted to a rail for bleeding and the head may be removed at that time. The feet are removed and the shanks and breast are skinned with a knife, but the knife is usually not used for removing the remainder of the pelt. Sheep and lamb skin, as well as the natural fine membrane called the "fell" which remains on the carcass, are so tender that they are easily cut with a knife. Instead, fists are forced in between the skin and the fell to remove the pelts. Experienced men can do this job rapidly without damaging the pelts or the appearance of the carcass. The fell helps prevent shrinkage of the carcass in the cooler and also gives the carcass a smoother appearance.

Evisceration of all species is essentially the same. The sternum and pelvic bone of cattle and hogs are split with a saw or knife for easier evisceration. In sheep only the sternum is split. Evisceration proceeds with the animals hanging from the rail by the rear shanks. Reproductive organs and intestines are first cut loose and the remainder of the viscera (stomach, esophagus, lungs, heart, liver, etc.) follows (see also Figure 2-8, page 30). Kidneys, and the fat which surrounds them, are usually left in beef and lamb carcasses but are removed from pork carcasses. By tradition, the spleen is usually left in lamb carcasses.

In plants under federal or state inspection, viscera removed from an animal must be identified with the corresponding carcass until checked by the inspector (Section 24.2 and Figure 2-8). The liver and heart are then separated from the remainder of the viscera. Value of the viscera is further discussed in Section 24.11.

To facilitate rapid chilling of the meat, large carcasses are split down the backbone with a cleaver or saw. Beef carcasses are split completely and sides are handled separately. Pork and veal carcasses are usually split to the top of the shoulder or neck.

[2] J. Wismer-Pedersen and Hans Rieman, *Am. Meat Inst. Found. Circ. 61*, p. 89, 1960.

Carcasses are then thoroughly washed and prepared for the cooler Beef sides are usually covered with a "shroud" This heavy piece of cloth, previously soaked in salt water, is pulled tight around the outer portion of the side so that after chilling when the shroud is removed the side will present a smooth, neat appearance The small amount of salt bleaches the outer layer of fat The shroud also prevents some cooler shrinkage The fell on sheep carcasses serves the same function, so does the skin on pork carcasses and the hide on light calves

24.2 Inspection

A circular purple stamp (Figure 24-3) on a cut of meat bearing the message 'U S Inspected and Passed" means that the meat was processed in a federally approved plant, is wholesome, and is safe for human consumption The stamp is applied by trained inspectors, employed in the Meat Inspection Division of the USDA It appears on all U S meat and meat products which move in interstate or foreign commerce

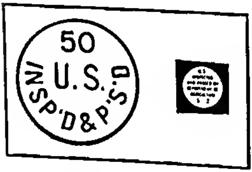


Figure 24-3. The federal meat inspection stamp on the left is applied to each wholesale cut on carcasses approved The number refers to the plant where the stamp was applied The inspection statement on the right appears on packages of processed meat items such as chili or wieners

The Meat Inspection Act of 1906 provides that all plants which handle meat or meat products to be shipped interstate be equipped to assure sanitary preparation, handling, and storage [3] Included in the requirements are an ample supply of clean water, an adequate sewerage system, abundance of natural and artificial light, adequate ventilation, and ample hot water for cleaning Plants which sell within a state need not comply with federal regulations but are subject to any state rules which exist

Since meat inspection is mandatory in plants which come under the federal law, the government hires pays, and assigns the meat inspectors The only costs born by the packer are equipping and maintaining the plant according to requirements, and losses resulting from condemnation of animals, carcasses, or product

[3] *Armour's Analysis* 5 2, Armour & Co , Chicago, 1956

Federal meat inspection applies to cattle, calves, swine, sheep, goats, and their meat food products. Horse meat is covered by different regulations; poultry and poultry product inspection is conducted under the Poultry Division, Agricultural Marketing Service of the USDA.

Meat may be inspected three times, before slaughter (ante-mortem), after slaughter, and as product—ham, sausage, chili, etc.

All animals entering an inspected plant are checked while they are in motion and also at rest. If they display symptoms of conditions that would render their meat unfit for food, they are tagged "U.S. Condemned." Animals whose soundness is doubtful are tagged "U.S. Suspect" and are slaughtered separately from other animals. "Suspected" animals are given a more thorough post-mortem examination. Animals bought by the packer "subject to inspection" (Section 23.10) are also usually handled this way.

Inspectors, usually graduate veterinarians, are located at certain points along the dressing line to examine each carcass, head, and viscera. The lungs, liver, spleen, and heart, and also lymph glands on the carcass, are closely checked for evidence of disease. If evidence exists, each carcass or portion deemed unfit for food is marked "U.S. Inspected and Condemned," then consigned to sealed rendering tanks according to specific regulations. Usually, less than 0.25 per cent of the carcasses are condemned. Portions of a carcass may be condemned because of bruises or localized infections and the remainder of the carcass passed.

24.3 Cooling

Carcasses must be cooled rapidly and thoroughly to insure preservation. Coolers in packing plants are usually held at about 35° F. Large fans keep the cold air moving for more efficient cooling of the meat carcasses. Many coolers are equipped with germicidal lamps, preventing development of certain molds and bacteria which might contribute to spoilage.

Pork carcasses are usually chilled 18 to 24 hours before cutting. This allows the thicker portions, such as the ham and shoulder, to be completely chilled down to 35°. Also the pork fat becomes hard and therefore allows easier cutting of the carcass into wholesale and retail cuts.

Lamb and mutton carcasses are also cut, or loaded for shipment, after 18 to 24 hours in the cooler. Shipment, of course, must be in refrigerated rail cars or trucks.

Because beef carcasses are larger and thicker, complete cooling requires more time. External fat is usually hard enough that shrouds are removed 12 to 18 hours after slaughter, but carcasses are usually not cut until 30 hours or more have elapsed. Top quality beef is sometimes kept in the cooler longer for aging (Section 24.7).

24 4 Meat Grading

Just as the federal inspection stamp (Figure 24-3) signifies that meat bearing the stamp is fit for human food, the federal grading stamp (Figure 24-4) designates relative meat quality Reasons for having and using carcass grades were presented in Chapter 21

Figure 24-4 The federal meat grading stamp

Federal meat grading is not mandatory, except as may be required for U S military meat purchases or by ordinances in a few cities The meat grading service is available to processors who want it, the packers therefore pay the government for the service Many retailers demand USDA grades on the beef and lamb they buy Essentially no pork is "government graded"

Even though packers who use the grading service bear the cost, the men who do the grading are hired, supervised, and paid by the Meat Grading Branch of the USDA Graders are then assigned to a certain plant, or perhaps several adjacent plants

Where federal grading is employed, carcasses are usually graded after they have chilled in the cooler, and, in the case of beef, shrouds have been removed Grade specifications are more easily followed after carcasses have chilled and the fat is firm Beef carcasses are often "ribbed down" so the grader can appraise the quality of the lean in the eye muscle as well as the exterior of the carcasses Most lamb carcasses are not ribbed down for grading and leave the plant intact

Once the federal grader determines the grade he usually applies a temporary indicating mark A helper then "rolls" the carcass, so that the USDA stamp appears on every wholesale cut and on almost every retail cut from that carcass

Private grades which might be used by a certain packer are usually applied by a packer employee in the same manner (Figure 24-5) Though specifications similar to those used in USDA grades may be employed, the packer grade designation or stamp must be clearly different from those used by the USDA

Figure 24-5. A packer employee "rolling" a beef carcass with the packer's grade name. Almost every retail cut will carry the grade name. Also note the federal inspection stamp located on each wholesale cut. (Swift & Co.)

24.5 From Carcass to Cuts

Wholesale cuts of lamb, beef, and pork, and where they come from on the carcass are presented in Figures 24-6 and 24-7. Though most lamb leaves packing plants as an intact carcass, many heavy lamb, yearling, and mutton carcasses are broken into wholesale cuts. This allows more effective merchandising. Heavy lamb legs or loins are preferred by many hotels and restaurants, but they have little use for other parts of the carcass.

Though some beef is shipped to wholesalers, retailers, and restaurants as "quarters," an increasing amount is broken completely to wholesale or retail cuts in the plant. The needs of each individual buyer are more easily met. Cuts are sorted by weight groups and can be packed in boxes or crates for easier handling. Fat trim can go directly to rendering facilities in the plant and lean trim can be used for hamburger or prepared meat products.

Some processors have gone further in merchandising beef. A few prepare and sell retail cuts—steak, roast, or hamburger—in family sized, transparent, vacuum-sealed packages, bearing the packer brand name.

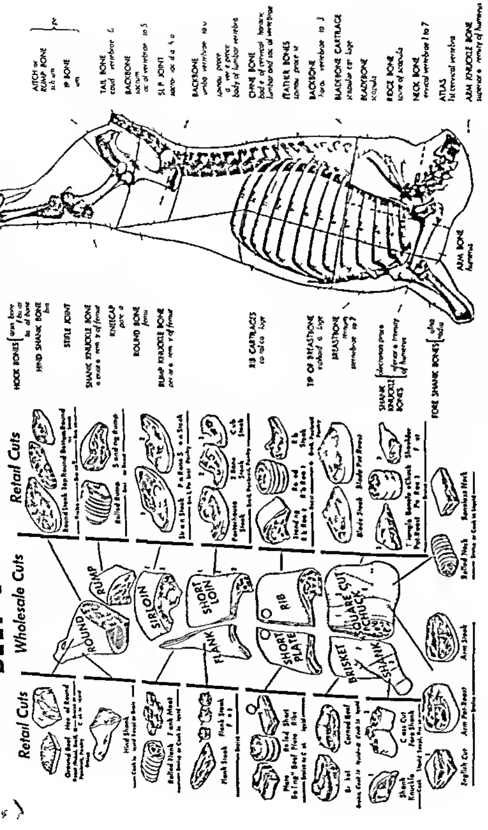


Figure 24-6. The beef carcass and the normal wholesale and retail cuts. The outline of the skeleton on the right, shows the bones that will be present in each cut. Observation of bones contained in retail cuts, then, helps to identify which part of the carcass a particular cut came from. (National Livestock and Meat Board)

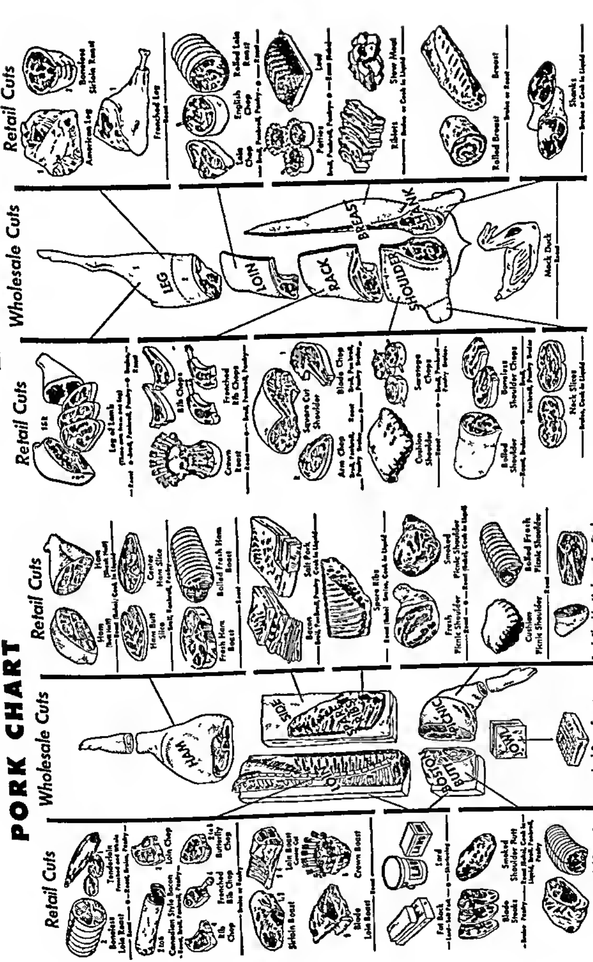

LAMB CHART
Wholesale Cuts
Retail Cuts
Retail Cuts
LEG
LOIN
RACK
SHOULDER
BREAST
SHANK
Mock Duck
PORK CHART
Wholesale Cuts
Retail Cuts
Retail Cuts
HAM
SIDE
SPARE RIBS
PICNIC
BOSTON BUTT
LOIN
JOWL
Jowl Bacon Square

Figure 24·8. A pork cutting line in a packing plant. Mechanization of cutting has been easier for pork because of relatively uniform size carcasses. (Geo. A. Hormel & Co)

Retailers merely distribute the product and contribute nothing to the processing.

Pork carcasses are nearly always reduced to wholesale and retail cuts by the packer because (1) hams, bellies, and sometimes other cuts are cured and smoked, requiring expensive equipment, and (2) the large percentage of fat trim can be rendered directly into lard by the packer.

Mechanization has reduced labor needs in cutting carcasses, though much skilled labor is still used (Figure 24-8). Because carcasses vary in size, shape, degree of fatness, and other characteristics, development of labor-saving equipment to handle carcasses has been slow.

Extremely low quality carcasses, such as cutter and canner grades of beef, the cull grade of lamb, yearling, or mutton, or extremely soft pork carcasses, are not merchandised as wholesale or retail cuts. The meat is certainly edible and usually is highly nutritious, but presents a less desirable appearance to the consumer. Such carcasses, or parts of carcasses, may be completely "boned out" at the plant. Edible meat is removed from the bones, then sold as boneless meat or used in one or more of a wide variety of prepared meat items such as sausages or canned meat products.

24.6 Lean and Primal Cuts

The term "lean cuts" is most used in reference to pork since great emphasis has been placed on leanness in recent years. The lean pork cuts are the trimmed ham, loin, and shoulder (Boston butt and picnic). On good quality, meat type carcasses these cuts contain about 65 to 70 per cent lean while the belly contains only about 35 per cent lean. Such pork carcasses should carry 50 per cent or more of their weight as trimmed lean cuts.

The term "primal cuts" refers to the more expensive cuts on a carcass. Prices of various wholesale cuts on a typical day are given in Table 24-1. In pork the primal cuts are the ham, loin, shoulder, and belly. Primal cuts of beef are the round, loin, and rib. Note that most of the

weight of the hind quarter of beef is composed of primal cuts. In lamb the leg, loin, and rack are the primal cuts, essentially the same portions of the carcass as in beef. The leg of lamb usually represents about half the value of a carcass even though it comprises only about one third of the weight.

Table 24-1. Prices per Pound of Wholesale Meat Cuts on a Typical Day

Choice Beef			Pork			Lamb		
Cut	Approx. percentage of carcass	Price per lb.	Cut	Approx. percentage of carcass	Price per lb.	Cut	Approx. percentage of carcass	Price per lb.
Round	19	$ .53	Ham	1.00	$ .41	Leg	33.00	$ .55
Loin	18	.73	Loin	15.00	.46	Loin	10.00	. 4
Rib	9	.54	Belly	11.00	.36	Rib	12.00	. 8
Chuck	25	.40	Boston butt	7.00	.36	Shoulder	23.00	.37
Shanks	6	.26	Picnic	.50	.34	Breast	17.00	.24
Brisket	5	.33	Spare ribs	2.00	.44	Shank	3.00	.24
Plate	8	.31	Jowl	3.00	.28	Trim	2.00	
Rump	3	.34	Trim	34.50				
Flank	5	.38						
Trim	2							

The percentage of trim is greater on pork because more fat is removed from the cuts at the plant and the belly is trimmed down to a standard size.

In live animal selection, whether for slaughter, feeding, or breeding, it is apparent that we should pick animals with a high proportion of the high priced, primal cuts. The percentage of the carcass which the cut comprises multiplied by the price per pound shows the relative importance of each cut in selection.

24.7 Aging and Tenderizing

Protein digesting enzymes[4] (proteases) present in fresh meat tissue will cause meat to become more tender in time. These enzymes apparently cause chemical breakdown of certain meat components, such as connective tissue. The enzymes are most effective at higher temperatures.

Special aging coolers are maintained at temperatures of 55° to 60° F. and equipped with ultra-violet light of the proper wave length to inhibit bacterial growth and spoilage. A significant improvement in tenderness results when meat is held at these temperatures and 80 to 90 per cent humidity for three days. The same effect results from aging two to three weeks at 35° F.

Aging meat involves some expense, so only the highest quality meat for the most discriminating customers is aged. Choice and prime beef and

[4] J. L. Sliwinski *et al.*, *Am. Meat Inst. Found. Bull. 45*, p. 20, 1961.

lamb carcasses, or primal cuts from these carcasses, are more often aged Besides the special cooler and equipment, extra labor is involved in handling the carcasses or cuts The meat loses weight during aging and the surfaces of the cuts usually need to be trimmed away after aging

Other methods may also be used One leading Chicago steak house ages ribs and loins in stainless steel cans Bacterial growth is controlled by maintaining the right ratios of temperature, humidity, and pH, as well as the amount of oxygen available for bacteria growth Certain antibiotics might also be used to inhibit bacteria development (see Sections 26 2 and 26 7)

Lower quality meat is usually not aged because the slight improvement in quality does not merit the expense Also, beef or lamb with less external finish would shrink more Rather, purified enzyme preparations are used to improve tenderness of less tender cuts, especially beef

One large meat processor[5] presently tenderizes considerable beef by pre slaughter injection of a purified enzyme solution, papain, into the blood stream The enzyme is quickly pumped to all tissues by the heart Much remains in tissue capillaries with circulatory fluid, even after the animal is bled

The enzyme has little opportunity to cause tenderization until cuts are heated during initial stages of the cooking process Carcasses are chilled within a few minutes after slaughter Also, the enzyme is apparently not released from the capillaries into the muscle tissue until cooking begins This particular enzyme, at the concentration used, is most effective be tween 130° and 160° F

When temperature of the cut passes 160°, as cooking progresses, action of the enzymes is essentially stopped, so there is little danger of "over tenderization'

This treatment apparently causes improved tenderness of beef in all grades, the benefit is largest in the lower grades

Essentially no pork is aged or treated with enzymes because tenderness is usually not a problem, even for people who want the best Hogs are marketed at a young age when the lean is relatively tender, and pork contains sufficient fat to make the meat very desirable

24 8 Curing and Smoking

Ham and bacon are the most popular cured meat products Picnics and Boston butts are sometimes cured and smoked Pork loins and tenderloins, beef brisket, and a few other cuts may be cured and smoked as specialty items

Curing and smoking procedures vary among processors and according to the type and size of product Curing is a preservation process, smoking adds a distinct flavor but also helps in preservation (Figure 24-9)

[5] Paul Goesser, Swift & Co, private communication 1961

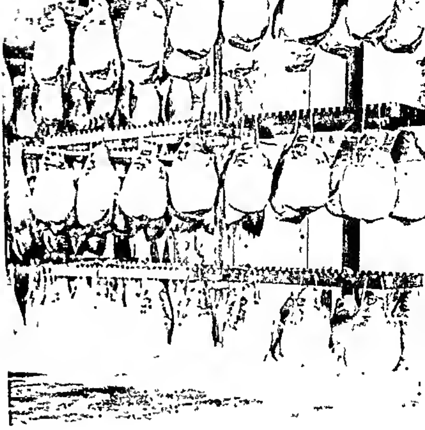


Figure 24-9. Removing hams from a stainless steel smoke oven. Temperature and smoke density in the ovens are closely controlled. (Swift & Co.)

Salt, the main ingredient in curing solutions, promotes preservation by its mere presence in meat tissue, since many bacteria will not grow in high concentrations of salt. The salt also promotes dehydration of tissue cells, further inhibiting bacterial growth. Sugar is usually included in a curing formula to help maintain desirable flavor and color of cured meat. A small quantity of potassium nitrate is also used to promote a bright pink color. Processors may add other distinctive flavors to their curing solution.

The curing ingredients are usually injected into the fresh cuts in solution and the cuts are then rubbed with a dry cure. This allows a uniform and rapid cure throughout the cut. Formerly, most bellies were only rubbed with dry cure and packed in special rectangular cans; hams were packed in a barrel in a liquid brine cure. Much time had to elapse—up to two weeks for bellies and six weeks or more for hams—for the cure to penetrate the entire cut. Such procedures were costly and not adapted to assembly line processing.

Time of cure depends on size of cut. Using present methods bellies cure in about two days, and hams in about two days *per pound*. Curing solution is injected into fresh pork bellies through a battery of needles. Hams are cured by use of a longer needle injected in several locations or by injecting the curing solution into a main vein under pressure. The solution is then distributed via the capillaries to all parts of the ham.

Cured cuts to be smoked are hung on racks in specially constructed smoke ovens, and are usually smoked about 18 hours at 125° to 135° F. Smoke to penetrate the cuts is usually generated from chips of some nonresinous wood, such as hickory, apple, oak, or maple. More time is required if the smokehouse temperature is lower. One packer has experimented with an assembly line smoking procedure. Bellies are negatively

charged then exposed to positively charged smoke particles Electric attraction causes rather complete smoke penetration.

Many hams are sold as "ready to eat" hams These usually have been held in the smokehouse 18 to 24 hours The interior of the hams must reach 155° F and be held at that temperature for at least two hours Trichinae, found in a very small percentage of pork, are killed by this treatment. Curing and smoking procedures, as well as other steps in meat processing are closely checked by employees of the Meat Inspection Division, USDA.

24 9 Other Processing Steps

The continued preparation of a large number of meat items in a typical packing plant would make a lengthy story The story would include many things, from freezing, slicing, and packaging cured and smoked bacon (bellies) to formulating and canning chili Some packers specialize in certain prepared meat items such as chili, wieners, or unique sausages, and may buy extra meat trimmings and ingredients from other packers so they can produce enough to fill orders In some cities, companies have developed to produce *only* such prepared meat items

Dozens of kinds of sausages are produced in American meat processing plants Wieners and bologna are probably the most popular Wieners usually are made from a mixture of beef and pork trimmings, finely chopped, and mixed with certain spices and flavors This mixture is forced into long, artificial casings, then linked by a special machine, cooked, and perhaps smoked. Cooking solidifies the inside of the wiener Another machine then removes the artificial casing, yielding "skinless franks" (Figure 24-10) Meat inspectors check here, too, on processing equipment and methods By chemical analysis of finished wieners they make sure the wieners contain sufficient lean meat.

Though artificial casings are used most commonly for sausages, natural casings are sometimes preferred and used for special types of sausages Natural casings—intestines of lambs, hogs, or cattle—are rather expensive because they must be washed and trimmed

Tongue, considered a specialty meat item, may be sold fresh or smoked Some is also used in prepared meat items Heart and liver are usually sold fresh, though they too might be used in special sausages or other prepared meats

In recent years packers have learned to merchandise certain meat cuts through new channels One packer, for example, developed a process for canning a special ham loaf, so that it could be stored at room temperature for long periods This has provided a tremendous outlet for the trimmings which remain after boning hams extra large hams which retailers can't sell effectively, or surplus ham available after marketing peaks

Figure 24-10. Frankfurter skinning machines in operation Striped cellophane is used for the casing so effectiveness of the skinning machines can be more easily checked. (The Rath Packing Co)

Soups and canned meats, as well as chili, provide outlets for meat that cannot be effectively merchandised as retail cuts. To produce such items it is apparent that the packer becomes more than a "disassembler" of meat animals. He must also buy other ingredients, formulate these specialty items, and be equipped to produce them.

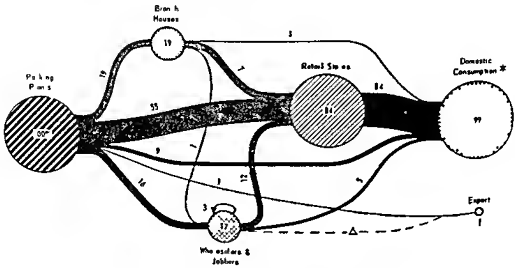
24.10 Meat Distribution[6]

In 1954 there were 4,357 independent meat wholesalers operating in the United States and 664 packer branch houses. These serve as a major link between packing plants and retailers, hotels, and restaurants, though many packers serve customers directly from their plant with truck routes. The number of independent wholesalers almost doubled between 1929 and 1954, while the number of packer branch houses declined about 40 per cent.

An increase in the number of large food store chains, and also collective or cooperative buying by certain groups of independent grocers, have caused further changes in meat distribution patterns (Figure 24-11). Many such groups deal directly with packers on large purchases, then distribute the meat items to their various stores. Probably over 40 per cent of the meat sold at retail is currently handled in this manner. Some food store chains operate their own packing plants, so buy their meat supply as live

[6] Willard F. Williams, *J. Farm Economics*, XL:315, 1958

MEAT DISTRIBUTION CHANNELS †
United States, 1954



ALL FIGURES EXPRESSED AS PERCENTAGE OF TOTAL VOLUME BASED ON VALUE OF MEAT
† INCLUDES FRESH FROZEN CURED AND PROCESSED MEAT AND MEAT PRODUCTS
* INCLUDES HOUSEHOLD CONSUMERS, INSTITUTIONS AND OTHER LARGE USERS   Δ LESS THAN 0.5 PERCENT

Figure 24 11 Meat distribution channels in 1954 emphasize the direct movement of meat from packing plants to retail stores

animals on markets or on farms and ranches A few operate commercial feed lots

The growth of independent wholesalers is apparently due to several factors First is a marked increase in meat consumption in hotels and restaurants served by such wholesalers Second, a number of shipper type packers are established in producer areas and must depend on wholesalers in meat deficient areas to distribute their product Also, existing packers have tended to specialize more, so also rely on wholesalers It may be, too, that increased labor costs and problems inherent in management of large packing companies with scattered branch houses resulted in some degree of inefficiency

Most packers or wholesalers employ many salesmen who regularly call on and quote prices to retailers, hotels, and restaurants There is much competition and the product is perishable, so the salesman's task is challenging Meat items sold are then delivered by refrigerated truck.

24 11 By-Products[7]

Many consumer items, from oleomargarine to footballs, are by products of meat processing By products are defined here as any product other

[7] *Armour's Analysis* 7 1 Armour & Co Chicago 1958

than meat, prepared meats, or specialty meats. From five to 30 per cent of the income received by packers from the sale of processed meat animals comes from such by-products, varying according to species, animal quality, and price fluctuations (see also Table 23-6, page 334). Pork carcasses usually yield a higher proportion of their total value as by-products, primarily because of the high proportion of fat trimmed off during processing. The pelt is the most valuable single by-product of sheep and the hide is the most important cattle by-product.

Cattle hides are the major source of leather, for shoes, luggage, purses, book bindings, garments, and athletic equipment. One company is experimenting with leather wall and floor tile. Hides vary in quality; those carrying brands or grub holes are less valuable because there is more waste in their use.

Beef cattle have thicker hides than cattle of dairy breeds. Steer hides, or hides from well-fed animals, are thicker than hides from cows or poorly fed cattle.

After slaughter, hides are cured by soaking in a salty brine for about 24 hours, or in piles with dry salt between hides for 30 days or more. The hides are then made into leather by tanning, so they will not be subject to bacterial action.

Most tanners are specialists and buy cured hides from packers. The tanner removes the hair and any flesh by machine. The hides are then immersed for several weeks in tanning liquors made from certain wood bark, or for a few hours in a liquid containing chromic salts. Most heavy, top quality hides are tanned by the former process to give maximum shock absorption, puncture resistance, and wear. Chrome tanning is used more for light cattle and calf hides.

Fats are a major by-product. Edible fats, kept fit for human consumption throughout processing, are rendered to make lard or tallow so are eventually used in spreads, pastries, candy, and other food items where shortening is used. Inedible fats are used for candles, glycerines and other chemicals, plastics, lubricating oils, and hundreds of other materials. They are also used in livestock feeds, especially for poultry and swine, because of their extremely high energy value.

Blood meal, meat and bone scraps, liver meal, and bone meal are also used in livestock feeds. Their names imply their origin, each product being dried after excess fat is extracted, and ground. Tankage is simply a mixture of blood meal with meat and bone scraps. See Table 6-4, page 80, for nutrient content of these feeds.

Wool, pulled from the pelts after slaughter, is made into clothing, blankets, etc., but also yields lanolin. This material is refined from wool grease and, because of its similarity to human skin secretions, has become popular as a base for many ointments and cosmetics.

Carpet padding, insulation, gaskets, furnace and air-conditioner filter

pads, plaster binder, small brushes, and dozens of other items are made from cattle hair Most hog hair is used for cushion padding, but is usually mixed with longer cattle or horse hair For effective use as padding, this hair must first be curled by machine

Glue and other adhesives are mostly protein and are derived from collagen, a type of connective tissue extracted from hide or bone Another type of animal adhesive is made from dried blood Though gelatin is chemically and physically very similar to glue and is made from the same materials, it is used mostly in foods

Over 35 different drugs or pharmaceuticals are purified from glands and organs removed during and after livestock slaughter ACTH, thyroid extract, and insulin are common to all Trypsin, a protein digesting enzyme from the pancreas, is used to liquefy pus and debris in wounds The liver yields an extract for treatment of anemia Many other examples could be given

24 12 The Packer and His Profit

The meat packing industry spends much money for advertising each year, telling producers and others that the packing industry is a low profit industry Figures such as those in the left column of Table 24-2 are often quoted

Table 24 2 Net Earnings of All U S Manufacturing Corps vs Meat Packers 1960*

	Per cent of sales dollar	Per cent of net worth
All manufacturing corporations	4 4	9 1
Meat packers	0 8	6 8

* *Financial Facts about the Meat Packing Industry* Am Meat Inst Chicago 1960

These figures tell a shocking story at first glance, but *remember* since meat is perishable, it is sold rapidly There is quick turnover of capital, much quicker than in most other industries

A more *realistic* way to appraise the relative profitability of meat processing is to compare profit *as a percentage of net worth* with other industries Even expressed in this manner, however, profit is usually not high—often between three and ten per cent

The most profitable years and seasons for packers are those of extremely heavy livestock production and slaughter (and usually low livestock prices) Packers apparently make money on volume Many costs are relatively fixed. Most equipment and coolers must operate, regardless of slaughter volume, sales, office, and administrative staffs are paid continually The industry is a high labor industry and the labor is highly unionized This means a minimum number of hours of employment usually must be guaranteed, regardless of slaughter volume

25

MEAT CONSUMPTION

How much meat do people eat? How does consumption of beef, pork, lamb, and poultry compare? Do income, occupation, location, religion, or season influence amount, species, or quality of meat purchased and consumed? What are the trends in meat consumption, relative to other foods? What factors cause these trends and will they continue? Available information on these questions will be discussed in this chapter.

The term meat in this chapter refers to beef, veal, pork, lamb, mutton, and poultry. Red meat includes all but poultry. Estimates given in charts, graphs, etc., are usually based on pounds of meat sold at retail with or without bone and does not include wastage or shrinkage that occurred in the packing plant or retail market. Meat purchased as soup, chili, wieners, etc., is also included.

25.1 Elasticity of Demand for Food

The demand for food is relatively inelastic. This means that total food consumption doesn't change much, even when the consumers' ability to buy food increases or decreases. In other words, the "American stomach" doesn't change much in size when consumer incomes go up or down.

Data to support the above accepted principle is difficult to obtain. Accurate estimates of the *pounds of food dry matter* consumed are not available. Food *volume* estimates, supplied by the Agricultural Marketing Service, USDA,[1] indicate that per capita food consumption increased 13 per cent from the 1935-39 period to 1960. During this time, however, per capita purchasing power increased much more than this. Increased purchasing power did not cause a corresponding increase in volume of food consumed.

Furthermore, an analysis of changes which occurred in *kinds* of food consumed (further discussed in Section 25.2) indicates that pounds of food dry matter probably did not increase even 13 per cent. Consumption of grain food products (85-90 per cent dry matter) dropped markedly,

[1] AMS, USDA, *National Food Situation*, May 1961.

while consumption of meat, eggs and some other high moisture foods increased

The amount of money spent for food per person per year did increase from the 1935 39 period to 1960 (Figure 25-1) The main reason, however, was inflation A second reason was that consumers were buying higher quality food items The slight increase in volume consumed probably contributed little to the increased expenditures These points are illustrated by the bottom half of the graph

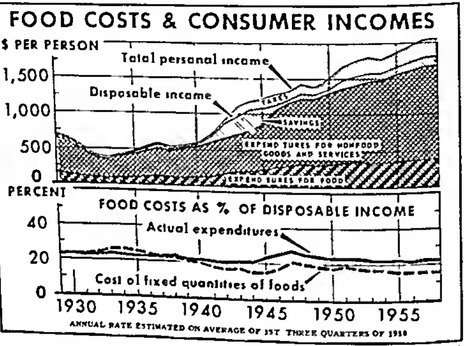


Figure 25 1 Expenditures for food have increased as disposable income has increased, but not as a percentage of income

Few consumer items have a demand as inelastic as that of food Though clothing and shelter are also considered essential, people buy more clothes and larger houses with more conveniences when they have more money to spend When money is scarce, they cut back Increases in disposable income cause people to buy more cars, more cameras, more sporting equipment, and more of other items that are generally classed as luxuries The demand for these products is elastic

This unique characteristic of food—relatively inelastic demand—is a basic principle for all in agriculture to understand Those who *produce* food, plus those who *service* the producers and *process* the food items, are subject to the principle Let it be considered an "occupational hazard" which contributes to surpluses and low prices when too much is produced

or a "blessing" to people in such occupations when consumer purchasing power is low. Even then, people still have to eat.

25.2 Meat vs. Other Foods

Though people tend to eat about the same quantity of food regardless of economic conditions, there might be significant shifts among the kinds of food consumed. Table 25-1 shows some of the changes in consumption of various types of food during a 25-year period.

Table 25-1. Per Capita Coosumptioo of Major Food Items*

	Average 1935-39	Average 1947-49	1959	1961
Red meats (carcass wt.), lbs.	127	148.5	159.5	161.2
Fish (edible wt.), lbs.	11	10.5	10.7	10.6
Eggs, (no.)	300	385	353	323
Poultry meat, lbs.	15.6	22.0	35.2	37.9
Dairy products (total solids), lbs.	68.4	72.6	69.1	67.0
Fruits, lbs.	154	151.0	123.1	118.4
Vegetables, lbs.	331.7	323.8	296.3	301.8
Grains, lbs.	214.5	184.5	161.6	161.5
Fats & oils (incl. butter), lbs.	45.4	42.4	46.2	46.7

*ERS, USDA, *National Food Situation*, February 1962.

One of the most significant changes noted in Table 25-1 is the decrease in consumption of *grain products*. The decline in *vegetable* consumption was caused mainly by a drop in potatoes, sweet potatoes, and beans. These particular vegetables and grain products are relatively low in protein but are high in starch (digestible carbohydrate). They are, therefore, considered "energy" foods.

During the period of time covered by data in the above table and since, Americans have decreased their human energy needs. They work fewer hours per week. They use more machines and do less strenuous physical labor. They walk less, ride more.

Further, there has been strong and effective publicity on the benefits of reduced body weight. Insurance companies, educational institutions, and others have shown data which says fat people die younger. People are more conscious of their appearance and want to be trim. The benefits of ample protein and less energy for continued good health, especially in older people, has been widely demonstrated. High protein, low calorie diets have been glorified, and rightly so.

At the same time, economic conditions in the United States have improved. Consumers have had more spendable income and, even with in-

flation, more purchasing power They have been able to afford the more expensive high protein foods, such as meat and poultry products Improved processing preservation and transportation of these more perishable foods may also have contributed to their increased consumption Also, in some later years heavy production of meat animals because of ample feed supplies resulted in heavy marketings and lower prices, animal products were therefore more easily afforded by the consumer

Though it is accepted that the total amount eaten per person doesn't change much, there is real competition among groups of food items, or even specific foods If consumption of one food increases because of consumer income, health, fad changes in relative food prices, effectiveness of merchandising or promotion and advertising, then consumption of some other foods will probably decline

Meat promotion, designed to increase consumption, is discussed in Section 25 8 Producers and processors of other food items—citrus, potatoes wheat, milk, and others—also spend much money on product promotion The net effect of these promotional programs is not apparent Certain ones have been very effective It is doubtful, however, that total food consumption (dry matter) will increase as a result of the combined campaigns

25 3 Trends in Meat Consumption

Per capita meat consumption increased from the pre-World War II era to 1961, but the rate of increase was not the same for all kinds of meat (Table 25 2)

Between the 1935 39 period and 1961, annual per capita meat consumption jumped 40 per cent Though less poultry meat than red meat is consumed, it is certainly significant that chicken and turkey consumption increased 125 per cent and 250 per cent, respectively Pork consumption

Table 25 2 Per Capita Consumption of Meats*

	Average 1935-39	Average 1947-49	1959	1961
Beef (carcass wt), lbs	55 6	65 6	81 4	87 8
Veal (carcass wt), lbs	8 1	9 7	5 7	5 7
Lamb and mutton (carcass wt) lbs	6 8	4 8	4 8	5 1
Pork (carcass wt excl lard), lbs	58 5	68 4	67 6	62 6
Chicken (ready to cook), lbs	13 4	18 7	28 9	30.2
Turkey (ready to cook), lbs	2 2	3 3	6 3	7 7
Total lbs	142 6	170 5	194 7	199 1

*AMS USDA *National Food Situation* February 1962

increased only 11 per cent, while veal, as well as lamb and mutton, declined. What are the reasons?

The marked increase in beef consumption was probably caused by several factors. Because beef and pork are consumed in largest quantity, they probably exert the greatest competitive effect on each other (Figure 25-2). Discussions of some of the factors follow: (1) Beef cuts, on the average, are more expensive than pork. Increased consumer purchasing power allowed people to shift some purchases from pork to beef. Beef has long been considered more of a luxury item than pork. (2) Beef is leaner than pork, on the average. Since people needed less energy and became more weight conscious, more people preferred the leaner beef. (3) U.S. farm population declined and urban population increased. And surveys show city people eat more beef and less pork than farm people (see also Section 25.5).

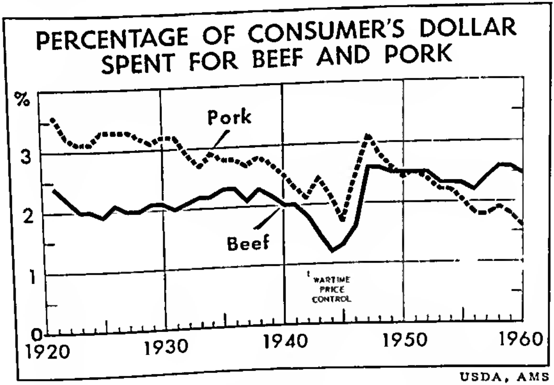


Figure 25-2. Percentage of consumer income spent for beef and pork. Between 1930 and the middle 1950's the proportion spent for pork declined; beef increased.

Decreased lamb consumption between the 1935-39 period and 1961 might be due to some of the basic causes discussed previously, but there are other consideratioos. First, lamb is a luxury meat. Higher income families eat more (Section 25.6), but consumption has gone down during a time of increasing consumer purchasing power. The reason, then, must lie in the areas of production and distribution rather than in demand. The study of long-term trends and cycles in livestock numbers (Chapter 22)

disclosed that sheep population grows during economic depressions and recessions, but constricts markedly in times of farm prosperity Production dropped sharply during World War II

As lamb production declined, distribution problems arose that may have further discouraged production A 1955 survey, for example, indicated that *fewer than half* of the retail stores in the U S handled lamb People patronizing the other half of the stores lost the habit of eating lamb Also, because lower volume means distribution and handling costs are probably higher per unit, lamb had to be offered for sale at relatively high prices

Several factors contributed to increased consumption of poultry meats (1) Relative production costs went down Great strides in nutritional and genetic knowledge provided rapid growing strains of chickens and turkeys that utilize feed efficiently Concentration of production in fewer, but larger, units further lowered production costs and much competition within the industry helped hold down retail prices (2) Merchandizing was very effective This included promotion, attractive packages, and attention to uniform quality of product Chicken is often sold as packages of legs, thighs, gizzards, etc (3) Smaller breeds made turkey a year around family food item

Trends in meat buying habits other than the volume trends discussed above are apparent Consumers prefer higher quality cuts than formerly They want lighter weight cuts, and cuts or prepared items that can be cooked quickly and with little effort Housewives have more money to spend shop oftener, and want more variety in their meals A larger percentage of housewives work outside the home and therefore have less time to prepare meals

These factors certainly will influence livestock *producers* of the future, but will probably have greater impact on *processors* and *retailers* who are "on the firing line" in competing for the housewife's dollar

25 4 Geographical Preferences

A 1955 survey[2] indicated that per capita meat consumption in the southern states is lower than in other parts of the country Consumption was highest in the north central area, where meat animal population is most intensified The South was lowest in per capita consumption of beef, veal, and lamb, but highest in pork These consumption differences are probably due more to tradition income, and other factors than to location *per se*

Results of the one week survey are given in Table 25-3 The information is of limited significance since it covers only one week, but the results are not surprising Lower pork consumption in the Northeast is probably a reflection of income and exerted demand for meat items with

[2] AMS USDA *Consumption Patterns for Meat* May 1958

Table 25-3. Total Red Meat and Pork Consumption in the U.S (Pounds per person in one week, Spring, 1955)

	Red meat, lbs.	Pork, lbs.
United States	3.02	1.14
Northeast	3.07	0.98
North Central	3.37	1.23
South	2.57	1.26
West	3.31	1.00

*AMS, USDA, *Consumption Patterns for Meat*, May 1958

a higher luxury index (Section 25.6). The difference in pork consumption between the north central and western states is probably explained by the fact that most pork is produced in the north central area and little is produced in the West.

Note in Table 25-3 that about half the red meat consumed in the South was pork, while in other areas pork represented only about one third of the red meat consumed. And, until the 1950's, most southern states produced much less pork than was used there. This indicates a demand for pork, in preference to beef and other meats, strong enough to pay extra transportation costs. (Even with these costs pork is usually cheaper per pound.) Southerners like cured pork, too, perhaps another reason for the higher pork consumption.

Consumption of lamb and mutton varies greatly among sections of the country (Figure 25-3).[3] Though 65 per cent of the population, located in the 36 states between Nevada and Delaware, raise and feed about 90 per cent of the sheep, they eat only about 30 per cent of the lamb and mutton. The high consumption of lamb and mutton in the East and on the West Coast is probably greatly due to religion (Section 25.7) and income (Section 25.6).

Since most lambs are slaughtered at about 100 pounds and grade good or choice at slaughter, there can be little geographical preference for *quality* of lamb. There may be a tendency for lamb consumed in the western states to carry less finish because more lambs marketed there come directly from the range and are fed less grain. This difference is diminishing, however, as more grain is grown and more feed lots develop in the western states.

A vivid picture of the geographical preferences for beef was supplied by one of the large packers who asked its branch house managers scattered across the country what proportions of carcass weights and grades they would order for their trade territories if they could have their full choice.

[3] *Farm Journal*, Dec. 1955.

25.5 Rural and Urban Consumption

Farmers in the United States obtained half of their meat from slaughter of their own livestock, according to a 1955 survey [4] The proportion was less, but the quantity the same, compared to a 1942 survey This means farm meat consumption increased during that time, mainly because of increased meat purchases New and larger home freezers facilitated a shift from pork to beef on farms Formerly, because curing was the only practical method of most preservation on farms, most animals farm slaughtered were hogs

Farm families eat very little lamb or veal (Table 25-5) Most is consumed by urban dwellers Though farm families have shifted some to beef, they continue to eat more pork and less beef than those who live in cities No doubt this is primarily due to habit and custom, but may also be influenced by income The fact that farm people, who produce the meat, eat less total meat than urban people may be disturbing to some, especially when producers finance advertising campaigns urging people to "Eat More Meat"

Table 25 5 Rural vs Urban Meat Consumption in the U S (Pounds per person in one week Spring 1955)*

	U S	Urban	Rural nonfarm	Farm
Red meat	3 02	3 17	2 80	2 82
Beef	1 25	1 34	1 10	1 18
Veal	0 08	0 10	0 05	0 02
Lamb & mutton	0 09	0 12	0 03	0 02
Pork	1 14	1 13	1 15	1 21
Variety meats	0 10	0 11	0 08	0 07
Luncheon meats	0 36	0 36	0 39	0 32

*AMS USDA *Consumption Patterns for Meat* May 1958

Consumption of meat by farm families seems to be influenced more by income than consumption by urban families Farm families in low income groups eat much less meat than city families in the same income groups But if incomes are high—over $8,000—farm meat consumption is much higher

25 6 Consumption vs Income

Income is referred to, in the sections on geographical preferences and rural vs urban consumption as a major factor influencing amount, species and quality of meat consumed It probably has more influence on species and quality than on amount.

[4] AMS USDA, *Consumption Patterns for Meat* May 1958

Section 25.1 discussed the elasticity of demand for food and explained that it was rather low—people don't eat much more food when they have more purchasing power. Rather, they tend to eat less low quality food items and more high quality foods, such as meat, milk, and eggs. Consumers will also direct a larger part of increased purchasing power to higher quality meat, or species that have more esteem or luxury value, than to increased quantity.

Using economic terms, we might say that certain meats—lamb, veal, steak—have a greater elasticity of demand than pork, boiling beef, or luncheon meats. Higher purchasing power will cause increased consumption of the former, but will have little effect or perhaps a decreasing effect on the latter. It must be realized that the effect of increasing family income by $1000 per year may be considerably different when the shift is from $2000 to $3000 per year than from $9000 to $10,000.

Trends in consumption of various meats as influenced by income are given in Figure 25-4. It is apparent that average demand elasticity is highest for lamb, veal, and beef in that order. In other words, people consider lamb to be more of a luxury item. Evidence indicates that poultry meats, on the average, rank between beef and lamb on a "luxury index."

Pork is less of a status meat than beef or other meats. It is more of a stable dietary item for most families. Only in the West, where less pork is produced and pork on the table is more of a treat, is pork consumption correlated with income.

25.7 Holidays and Religious Beliefs

A few relations between meat consumption and holidays or religious beliefs are well known. Turkey has long been the traditional meat for Thanksgiving and Christmas, though ham is a favorite in some families.

Catholics[5] over seven years of age (30 million or more in the U.S.) are bound not to eat red meat and poultry on Fridays, and on about a dozen other special days scattered through the year. They depend on fish and dairy products as sources of animal protein on those days. More important as an influence on meat demand, Catholics between 21 and 59 years of age are bound to fast during the week days of Lent, which extends a month and a half, from Ash Wednesday to Easter. Fasting means, where health and work allow, only one full meal per day. Two other meatless meals, sufficient to maintain strength and not totaling another full meal, may be taken.

Hebrew dietary laws[6] have great influence on meat consumed by the

[5] Calendar for 1962, Budget Press, Salem, Ohio.
[6] *Agr Res Dept. Bull. 9*, Swift & Co., Chicago.

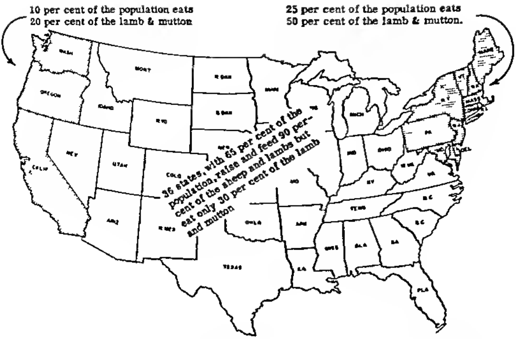


Figure 25-3. Lamb and mutton production and consumption in the United States Such patterns mean meat is hauled great distances from producer to consumer.

Some of the results are summarized in Table 25-4 and serve as a basis for further discussion. As you study this table consider the location of each city as well as the characteristics of the population in the city and surrounding territory.

Table 25-4. Approximate Proportions of Beef Grades and Weights Preferred*

	Grade				
	Star Deluxe	Star	Quality	Banquet	Dexter
Washington, D.C.	5	65	25	0	5
Richmond, Va.	0	20	70	8	2
Columbus, Ga.	0	10	38	25	27
Miami, Fla.	10	70	20	0	0
Reading, Pa.	0	25	65	10	0
Oklahoma City, Okla.	0	25	40	25	10
Portland, Ore.	5	20	30	30	15

	Carcass Weight				
	350-400	401-500	501-600	601-700	701-800
Washington, D.C.	0	0	0	50	50
Richmond, Va.	0	30	60	10	0
Columbus, Ga.	50	50	0	0	0
Miami, Fla	0	0	20	70	10
Reading, Pa.	0	50	50	0	0
Oklahoma City, Okla.	50	40	10	0	0
Portland, Ore.	10	30	30	20	10

*Armour's Analysis, 3.3, Armour & Co., Chicago, 1954.

Though there is an apparent outlet for every weight and grade of beef, there are large geographical differences in preference. The demand for high quality, heavy weight beef in the Washington, D. C. and Miami areas implies a high income population. Much of the beef consumed in Washington, D. C. is eaten in restaurants, perhaps by many who are on an expense account. Even those who aren't—the many tourists and visitors—eat in restaurants. Surveys have shown that people eat more meat when they eat out, and they eat higher quality meat.

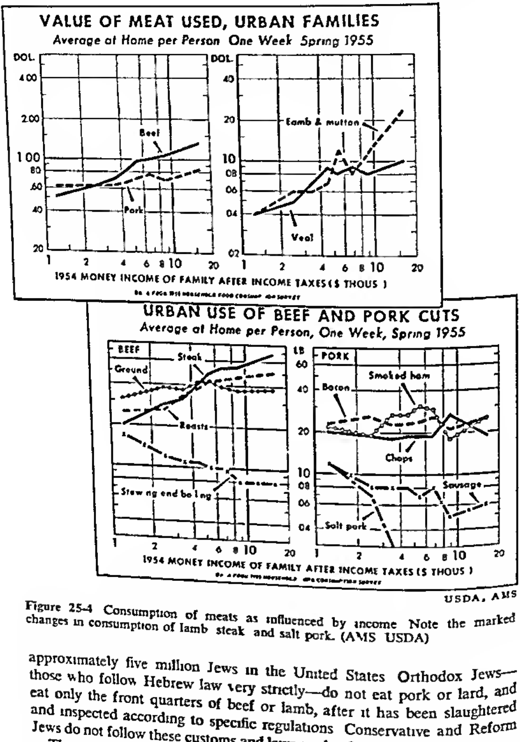
Consumption in Miami and some other main cities of Florida may reflect the income and preference of the many residents and visitors from the North. In keeping with the demand for heavy and high quality cattle, the Washington and Miami areas want nearly all steers, a few heifers, but no cow beef.

Richmond, Virginia provides an interesting comparison for Washington. Though only about 100 miles away, lower quality and lighter weight beef is preferred. Probably more of the Richmond beef eaters are permanent residents rather than commuters or tourists—they eat at home more, at restaurants less. And they may well have lower average incomes.

Columbus, Georgia, and Oklahoma City provide a contrast for Washington, Miami, or Richmond. Very light carcasses, from animals weighing under 900 pounds alive, with average or lower quality are desired. Columbus wants only 50 per cent steer carcasses and 35 per cent cow beef, reflecting the quality level preferred. Residents of these areas (remember the branch house would serve surrounding towns as well as the city) may have lower incomes, but it is also probable that their current tastes are influenced by habit and tradition. A larger percentage were probably raised in a rural, low income environment, where pork and lower quality beef were the main meats in the diet.

Geographical preferences for meat are not necessarily static. But they usually do have basic causes and shifts occur only gradually. Those involved in the meat industry should try to learn what these causes are so they might appreciate the stability of certain preferences and anticipate the shifts.

Current geographical preferences are probably caused by an interaction of factors, including the following: (1) Grain available for fattening cattle and sheep to higher grades or for raising hogs—until recent years, greatly lacking in the Southwest and South. Many natives of these areas may have seldom eaten choice or prime beef. (2) Cost of transportation—moving different grades of beef or lamb to all areas of the country. (3) Area of the country, rural vs. urban, income level, and other aspects of environment under which current residents of certain areas were raised—and the quality standards which resulted. (4) Current income level and quality standards, (5) Inertia—habit and tradition—of meat processors, wholesalers, and retailers.



USDA, AMS

Figure 25-4 Consumption of meats as influenced by income Note the marked changes in consumption of lamb steak and salt pork. (AMS USDA)

approximately five million Jews in the United States Orthodox Jews—those who follow Hebrew law very strictly—do not eat pork or lard, and eat only the front quarters of beef or lamb, after it has been slaughtered and inspected according to specific regulations Conservative and Reform Jews do not follow these customs and laws as closely

The required procedures for slaughtering beef intended for Jewish consumption is discussed in Section 24 1 According to a Biblical command forbidding Jewish people to eat blood and certain areas of fat, some of the veins and fat are removed from Kosher beef and lamb Removal of

the veins and undesirable portions from the hindquarters would leave the meat in shreds—unattractive, difficult to cook and handle, and very expensive because of the high labor cost. Therefore, Orthodox Jews utilize forequarters of high quality beef and lamb; the hindquarters are readily sold to restaurants and hotels.

Much of the beef and lamb intended for the Kosher trade is slaughtered near the place of consumption. There are several reasons. The Orthodox Jewish faith requires that meat be sold within 72 hours after slaughter, or be given a special washing. Even after such washing the meat is often difficult to sell. Also Kosher meat dealers prefer to buy their beef and lamb immediately after slaughter because it is easier to remove the veins before the meat is chilled. Therefore, purchase of high quality cattle and lambs by packers at markets, for the Kosher trade, is timed accordingly.

Special Jewish holidays also have significance to the meat producer and processor. Because the lunar calendar of 354 days is followed rather than the Gregorian calendar, the holidays are difficult to plot. Kosher slaughter is forbidden on Saturdays and there are thirteen Jewish holidays during the lunar year on which Kosher slaughter is forbidden. In two cases, four such days occur within a ten-day period, and in two other cases, two successive days are designated. These holidays, then, might have a marked influence on demand for high quality, well-finished cattle and lambs at markets where animals are normally purchased for the Kosher trade, especially if they follow or precede a three-day weekend.

25.8 Promotion of Meat and Meat Products

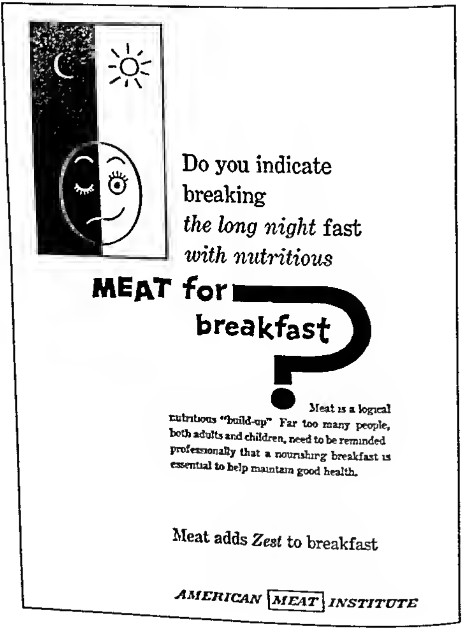
Meat is a competitor of other high protein foods of animal origin, such as cheese or eggs, or of fish. Meat also competes, to a degree, with other kinds of food. Mrs. Housewife has a choice—cereal vs. bacon and eggs for breakfast, bean soup vs. hamburgers for lunch, or a mixed casserole vs. pork chops for dinner. Most Americans eat meat at least twice a day but, there is still competition with nonmeat food items. Lard competes with vegetable oils for cooking and baking.

Most promotion and advertising is aimed at urging the consumer to buy *more* of a commodity, or to buy a *higher quality* product costing more money. This is certainly true for meat. Much promotion is based on the *nutritional* value of and need for plentiful quantities of meat in the diet, especially for youth and for elder citizens. Some promotion is based on *enjoyment*—flavor, aroma, juiciness, tenderness—that comes from crisp bacon, beef roast, or cured ham. Though some advance the idea that there is "prestige" in eating more meat, there is less of this type of promotion for meat than for most consumer items.

Processors and retailers naturally promote meat. It is the processor's main business. Retailers consider meat a relatively high profit item, so spend considerable amounts on meat advertising.

Many organizations sponsor meat promotion on a national scale. The National Livestock and Meat Board, representing producers, markets, processors, and retailers, and with a staff of 40 or more people, has an extensive promotional program They provide professional talent and visual aids for radio, television, cooking schools, meat exhibits, and cutting demonstrations, as well as teaching materials for use in schools and

Figure 25-5. The above advertisement was designed for medical publications Note the medical terminology (Am. Meat Inst.)



colleges. The operations of this group are financed by contributions from growers and feeders, deducted by marketing agencies at marketing time, and matched by packers. Current contributions per head made by each group are two cents for cattle, two thirds of a cent for calves and hogs, and two fifths of a cent for sheep and lambs.

The American Meat Institute, a national trade association for meat packers, also provides meat promotional materials in the form of films, booklets, and teaching aids. In addition, they finance considerable meat advertising in national magazines (Figure 25-5).

Many national and state organizations, such as the National Beef Council, the National Swine Grower's Council, and the American Sheep Producer's Council, have developed "self-help" programs to finance promotion of their products.

26

MEAT TECHNOLOGY

Meat technology includes the study of meat from the standpoint of the *consumer*, as a food which supplies both nutrients and pleasure, and from the standpoint of the *processor* and *distributor*, as a perishable product to preserve and handle. Appraisal of meat produced under different feeding and management programs is also a part of meat technology. In fact, much current research is aimed at establishing reliable appraisal techniques for evaluating meat as a food. Nutrient content can be checked chemically, but evaluation of meat flavor, aroma, juiciness, and palatability is less easily done.

Various preservation techniques are studied in meat technology, not only to measure their effectiveness in preventing spoilage, but also to determine if they affect nutrient value or palatability.

26.1 Nutritive Value

Protein content of meat varies from 30 to 80 per cent, on an air dry basis, depending primarily on degree of fatness. Of course most meat isn't eaten air dry, but in order to compare fairly the nutrient content of foods, such comparison should be made on the basis of comparable dry matter. Approximate nutrient content of certain meat cuts and other selected foods is given in Table 26-1. Discrepancies in the table are caused by collection of data from numerous, scattered sources.

Certain producers of cereal products have used the descriptive phrase "more protein than meat itself" in advertising. Some dry cereals may have a higher percentage of protein than certain cuts of fresh meat, but when figures are adjusted for the extra water meat contains, the protein content of meat is usually much higher.

Human dietary needs for essential amino acids (components of protein) are similar to those of other non ruminants discussed in Chapter 6. Human diets composed primarily of vegetable material are usually lacking in the same critical nutrients that all plant swine rations lack. Meat contains the dietary essential amino acids, as well as other amino acids in satisfactory proportions.

Because of the high content of important amino acids needed for tissue building, meat is especially important in the diets of children, who are

Table 26-1. Approximate Nutrient Content of Certain Meats and Other Foods, Ready to Eat*

	Dry matter, %	Protein, %	Carbohydrate, %	Fat, %	Calories per lb.	Vit. A, I.U./lb.	Riboflavin, mg./lb.
Lean beef	40.0	32.0	trace	8.0	1,067	trace	0.77
(2.25)[1]	90.0	72.0	trace	18.0	2,400	trace	1.73
Lean pork	47.0	35.0	—	11.0	1,130	trace	0.82
(1.91)	90.0	67.0	—	21.0	2,158	trace	1.57
Lean lamb	38.0	29.0	0.7	8.0	913	trace	1.40
(2.37)	90.0	69.0	1.7	19.0	2,164	trace	3.32
Bacon	87.0	12.0	1.4	53.0	1,425	—	0.75
(1.03)	90.0	12.4	1.4	54.6	1,468	—	0.77
Liver, beef	43.0	20.0	6.0	3.0	617	60,000	150.00
(2.09)	90.0	42.0	12.5	6.3	1,290	125,400	313.00
Corn flakes	96.0	7.0	85.0	trace	1,760	—	0.48
(0.94)	90.0	6.6	80.0	trace	1,654	—	0.45
Potatoes, baked	25.0	2.1	14.0	trace	288	trace	0.13
(3.6)	90.0	7.6	50.4	trace	1,037	trace	0.47
Eggs	28.0	11.0	1.0	11.0	840	4,800	1.12
(3.46)	90.0	38.0	3.5	38.0	2,214	16,608	3.88
Whole milk	13.0	4.0	5.3	3.5	330	1,000	0.84
(8.92)	90.0	27.7	38.7	24.0	2,284	8,920	5.81
Skim milk	10.0	4.0	5.7	trace	180	25	0.88
(9.00)	90.0	36.0	51.3	trace	1,620	225	7.92
Chicken, no bone	29.0	21.0	—	4.5	610	427	0.80
(3.10)	90.0	65.0	—	14.0	1,891	1,324	2.48

*Data collected from several sources, including USDA, *1959 Yearbook of Agriculture*, "Food"; Ruth M. Leverton, *Am. Meat Inst., Proc. of Ninth Res. Conf. Chicago*, *101*, 1957; B. S. Schweigert and Barbara J. Payne, *Am. Meat Inst. Found. Bull. No. 30*, 1956; P. T. Ziegler, *The Meat We Eat*, The Interstate Printers and Publishers, Danville, Ill., 1954.

[1] Figures in parentheses are the pounds of food in natural state equivalent to one pound of air-dry food (90 per cent dry matter). This allows comparison of nutrient content of foods on a uniform dry matter basis.

growing rapidly, and older people, whose amino acid needs for tissue repair may have accelerated. High protein diets, including generous portions of meat, are often recommended following surgery or after accidents that cause many wounds and considerable loss of blood.

Energy value of meat varies according to the cut, degree of finish, and proportion of the fat actually eaten. Many people trim excess fat carefully and eat only the lean.

Chapter 4 explained that three classes of nutrients—carbohydrates, fat, and protein—supply energy. Fat consumption varies, and meat contains only insignificant amounts of carbohydrate. So, in most cases, protein is the main potential energy source in meat. But many of the amino acids are used to build tissue or to make enzymes and hormones. Also, protein has

26

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(2.25)[1]	90.0	72.0	trace	18.0	2,400	trace	1.73
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(1.91)	90.0	67.0	—	21.0	2,158	trace	1.57
Lean lamb	38.0	29.0	0.7	8.0	913	trace	1.40
(2.37)	90.0	69.0	1.7	19.0	2,164	trace	3.32
Bacon	87.0	12.0	1.4	53.0	1,425	—	0.75
(1.03)	90.0	12.4	1.4	54.6	1,468	—	0.77
Liver, beef	43.0	20.0	6.0	3.0	617	60,000	150.00
(2.09)	90.0	42.0	12.5	6.3	1,290	125,400	313.00
Corn flakes	96.0	7.0	85.0	trace	1,760	—	0.48
(0.94)	90.0	6.6	80.0	trace	1,654	—	0.45
Potatoes, baked	25.0	2.1	14.0	trace	288	trace	0.13
(3.6)	90.0	7.6	50.4	trace	1,037	trace	0.47
Eggs	26.0	11.0	1.0	11.0	640	4,800	1.12
(3.46)	90.0	38.0	3.5	38.0	2,214	16,608	3.88
Whole milk	13.0	4.0	5.3	3.5	330	1,000	0.84
(6.92)	90.0	27.7	36.7	24.0	2,284	6,920	5.81
Skim milk	10.0	4.0	5.7	trace	180	25	0.88
(9.00)	90.0	36.0	51.3	trace	1,620	225	7.92
Chicken, no bone	29.0	21.0	—	4.5	610	427	0.80
(3.10)	90.0	65.0	—	14.0	1,891	1,324	2.48

*Data collected from several sources, including USDA, *1959 Yearbook of Agriculture*, "Food"; Ruth M. Leverton, *Am. Meat Inst., Proc. of Ninth Res. Conf. Chicago*, 101, 1957; B. S. Schweigert and Barbara J. Payne, *Am. Meat Inst. Found. Bull. No. 30*, 1956; P. T. Ziegler, *The Meat We Eat*, The Interstate Printers and Publishers, Danville, Ill., 1954.

[1] Figures in parentheses are the pounds of food in natural state equivalent to one pound of air-dry food (90 per cent dry matter). This allows comparison of nutrient content of foods on a uniform dry matter basis.

growing rapidly, and older people, whose amino acid needs for tissue repair may have accelerated. High protein diets, including generous portions of meat, are often recommended following surgery or after accidents that cause many wounds and considerable loss of blood.

Energy value of meat varies according to the cut, degree of finish, and proportion of the fat actually eaten. Many people trim excess fat carefully and eat only the lean.

Chapter 4 explained that three classes of nutrients—carbohydrates, fat, and protein—supply energy. Fat consumption varies, and meat contains only insignificant amounts of carbohydrate. So, in most cases, protein is the main potential energy source in meat. But many of the amino acids are used to build tissue or to make enzymes and hormones. Also, protein has

a high "specific dynamic action"—meaning that much energy present in the meat is used up while the body is metabolizing the protein. So, in effect meat is *not* necessarily a high energy food in terms of increasing weight. In fact, meat is the major food in many *reducing diets*. It has a low "net" energy value and because people on diets usually eat less total food, meat helps supply some of the vitamins and minerals they would otherwise get from a normal intake.

Most meats compare favorably with other foods as sources of critical vitamins (Table 26.1) and minerals. Liver, and certain other variety meats are especially high in these nutrients. The liver is the site of active metabolism in the animal body, where many vitamins and trace minerals serve as catalysts in important reactions, and is also a storehouse for many such nutrients.

26.2 Tenderness

Tenderness of meat is distinctly important to the consumer, having much to do with the pleasure derived from eating meat. The topic of tenderness has been alluded to in previous chapters, but usually in a rather vague way. The main reasons for the vagueness are (1) there is no completely satisfactory way to measure tenderness (Figure 26.1) and (2) factors which influence tenderness are not fully known and understood. Hence the meat technologist has much to accomplish in this area.

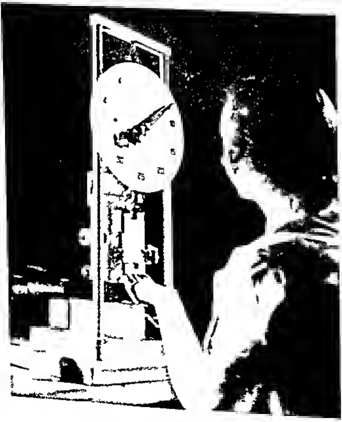

Figure 26.1 Mechanical technique for measuring tenderness in meat. Dial shows pounds of pressure required to cut a core of meat. Machine is accurate but doesn't necessarily duplicate the cutting and grinding action of teeth. (Am. Meat Inst. Found.)

It is known and widely recognized that meat may vary greatly in tenderness. There is variation among species, among animals within a species, and from one cut or muscle to another within a carcass. Variation among animals raised in the same environment and slaughtered at the same age, weight, and degree of finish suggests a genetic cause for some tenderness variation. Table 15-1 gave a heritability value of .60 for tenderness in beef, suggesting that heredity may be a *major* influence.

Some research[1] has indicated that tenderness is associated with the size of the muscle fibers—the smaller the fibers and the finer the texture, the more tender the meat. As animals mature and the size of each muscle fiber increases, there would be an expected decrease in tenderness. This change has been observed in some cases, but other changes during growth and maturity may counteract this effect.

Deposition of fat among the muscle fibers (marbling) as the animals grow and mature on a high energy ration tends to improve tenderness somewhat. There is disagreement and lack of sufficient knowledge concerning the importance of marbling in influencing tenderness. Correlations between degree of marbling and tenderness as measured by mechanical devices are lower than correlations between degree of marbling and tenderness as measured by a taste panel. Apparently the increased juiciness caused by the marbling makes taste panel members *think* the meat is more tender, whether or not it really is. In most studies degree of marbling has accounted for three to 11 per cent of the variation in tenderness.[2, 3]

Collagen and other connective tissue materials which hold the muscle fibers together apparently have some influence on meat tenderness.[4] Collagen and elastin are connective tissue fibers imbedded in a third connective tissue substance, which varies from a fluid to gelatin consistency and is called "ground substance." Knowledge of the importance of these connective tissue components in influencing tenderness is limited due to the difficulty in quantitatively measuring the amount of each in meat.

Certain feeding programs are known to increase the proportion of connective tissue[5] in meat. Feeding may, therefore, have relatively *direct* influence on tenderness, in addition to the fattening effect.

There is no available evidence to indicate that tenderness is associated with sex. Cows and bulls may be less tender, on the average, than heifers or steers simply because they are older when slaughtered. USDA carcass

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[1] Dorothy L. Harrison *et al.*, *Kansas Agr. Exp. Sta. Report 10*, 1959.

[2] G. H. Wellington and J. R. Stouffer, *Cornell University Agr. Exp. Sta. Bull. 941*, 1959.

[3] R. H. Alsmeyer *et al.*, *Am. Meat Inst. Found. Circ. 50*, p. 85, 1959.

[4] R. L. Hiner *et al.*, *Food Tech.* 9:80, 1955; Madge Miller and Joseph Kastelic, *J. Agr. and Food Chem.* 4:537, 1956; P. M. Nottingham, *J. Sci. Food Agr.* 7:51, 1956.

[5] E. Nelson McIntosh, D. C. Acker, and E. A. Kline, *J. Agr. and Food Chem.* 9:418, 1961.

grade is not a good indicator of tenderness, there is extreme variation within all grades

Muscles which have been used more during the animal's life are usually less tender Muscles along the back, including the tenderloin (psoas major) and the eye muscle (longissimus dorsi) are relatively tender The eye muscle is the main muscle of the rib and loin, and extends into the chuck and rump (or corresponding cuts of lamb or pork). The tenderloin is the small muscle below the vertebrae of the loin

There is much current interest in finding a live animal trait that could be used to predict tenderness of meat Such a trait could be used, not only for appraising slaughter animals, but also in selection of feeders and breeding stock Recent studies[6] have indicated density and diameter of hair to be of little value as an indicator of beef tenderness

Tenderness of meat can be increased by aging, freezing, or treatment with enzymes Cooking also influences tenderness, but the effect varies so much among cuts and among methods of cooking that space does not permit a thorough discussion here

Aging, as a part of meat processing, was briefly discussed in Section 24 7 Historically, only high quality beef cuts used in the finer hotels and restaurants have been aged, because of the time, labor, and cost involved Recent development of high temperature aging techniques, however, may allow improved tenderness of most consumer cuts, even from lower grade carcasses Research by the American Meat Institute Foundation[7] has demonstrated carcasses can be tenderized in 24 hours at 110° F (Figure 26 2), the improvement in tenderness being comparable to traditional aging at 35° for two weeks In the high temperature aging, spoilage was prevented by injection of an antibiotic two hours prior to slaughter Individual cuts were also successfully tenderized at the same temperature, after infusion of a part of the carcass with an antibiotic and/or irradiation of the cut

Meat tenderization by enzymes[8] is centuries old, apparently first done in tropical countries where meat was wrapped with papaya leaves or boiled with unripe papaya fruit Fruit and leaves of the papaya tree contain a proteolytic enzyme, papain which *digests protein*, improving meat tenderness Other sources of effective proteolytic enzymes currently used in commercial meat tenderizers are bromelain (from pineapple stems), ficin (from the fig tree), fungal and bacterial enzyme secretions, and trypsin (from hog pancreas) Others may also be used Federally inspected meat processors were first permitted to use such enzyme preparations for meat tenderizing in June 1955, and less than three years later it was reported over 20,000 gallons of the potent materials were being used per month

[6] T C Cartwright *J Animal Sci* 18 1476 1959
[7] George D Wilson *et al* *Am Meat Inst Found Circ 50* p 33 1959
[8] Vincent S Bavisotto, *Am Meat Inst Found Circ 45*, p 67, 1958

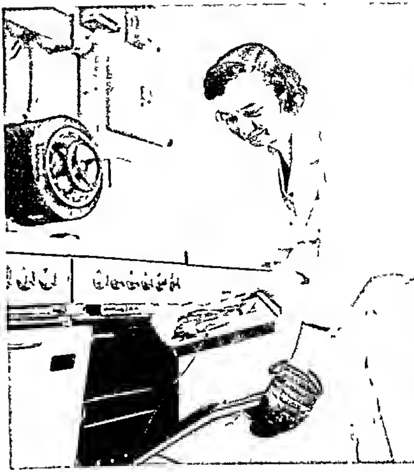


Figure 26-2. Steak, tenderized by high temperature aging, is broiled for taste panel evaluation. Thermocouple, inserted in steak to measure internal temperature, facilitates control of cooking temperature. (Am. Meat Inst. Found.)

Tenderizers are also available in dry form for home use, often in combination with certain seasonings.

Much is yet to be learned about the relative effectiveness of the various enzyme preparations. Most such materials are *mixtures*, and meat is composed of a mixture of different proteins. Each enzyme may be effective only on specific proteins. Research is currently directed toward standardization of enzyme mixtures and learning the effects of specific enzymes on the various meat components. (See also Section 24.7, page 349, concerning meat tenderization by injecting enzymes into the blood stream before slaughter.)

Freezing meat increases tenderness, apparently because fibers are ruptured by ice formation and connective tissue components are stretched and ruptured.[9] Lowering temperature to about —10° F. apparently causes a consistent increase in tenderness, but temperatures lower than this do not cause further tenderizing.

26.3 Flavor

What constitutes meat flavor? How can it be measured or quantitatively described? These two questions must be adequately answered before the effect of livestock management or meat processing on meat flavor can be accurately appraised. It is known that there is much variation in both

[9] Dorothy L. Harrison *et al.*, *Kansas Agr. Exp. Sta. Report 10*, 1959.

intensity and *type* of meat flavor, even within species, but little is known about how the two items can be effectively controlled

A further confounding factor is that people vary greatly in their meat flavor preferences, especially in regard to intensity of flavor

Observation indicates that flavor is more intense in meat from older animals and in muscles that are used most, such as those in shank, shoulder, and rear flank The tenderloin, which is very tender, usually has an extremely mild flavor Marbling is often credited with contributing to flavor, though the semiliquid fatty deposits in hot meat may be more effective in *carrying* the flavor to the taste buds than actually contributing to flavor, *per se*

Many assume that meat flavor is largely due to the amino acids, especially glutamic acid A salt of this acid, sodium glutamate, is a common ingredient in artificial meat flavorings and in prepared gravies, stews, and other prepared meat items

Preliminary research[10] suggests that most of the chemical factors contributing to beef flavor are nonvolatile, so apparently are different, in part, from those factors which contribute to aroma They apparently include certain sugars fats, and small molecular weight proteins[11] The colored portion of beef extract (broth) contains many of these flavor components, as well as some of the aroma factors

Loss of flavor in fresh meat displayed unwrapped in open cases may be evidence that some flavor components are volatile It may be, too, that the specific compounds are oxidized, or otherwise chemically changed, during display, causing the change in flavor

26 4 Aroma

Though it is difficult to distinguish aroma from flavor when eating meat, it is apparent that the chemical factors contributing to aroma are volatile Except in a few cases, meat aroma is neither apparent nor important to the consumer at the time of purchase, but is both important and noticed during cooking and serving As in flavor, there is great range in aroma—both present and desired, and little is really known about the components of meat aroma

Since pork fat is chemically less stable than beef or lamb fat, an oxidized, rancid aroma is more often observed Oxidative rancidity of fat is promoted by air and salt Cured ham or bacon, poorly wrapped may develop oxidative rancidity after several months' storage Though rancidity is usually restricted to exposed surfaces of the cuts, the aroma is still distinct and undesirable It is recommended that pork be kept in a locker or freezer not longer than four months, less time if cured

[10] George W Kurtz *Am Meat Inst Found Circ 50* p 95 1959
[11] O F Batzer *et al*, *Am Meat Inst Found Bull 45* p 22 1961

A unique and undesirable odor sometimes observed in pork is often referred to as "sex odor" or "boar odor." Though often associated with carcasses of mature boars, it is not restricted to them. It has been reported[12] in pork from gilts, barrows, and sows, as well as boars, and in every breed studied. It is not known that this odor is the same in every case reported, and the nature of the factors which contribute to the odor are not thoroughly known.

26.5 Marbling

The apparent and presumed benefits of marbling in meat have been previously discussed (Sections 9.1 and 23.4). The concern of the meat technologist is to establish the *validity* of these presumed benefits, and to develop techniques for *quantitatively measuring* the amount or desirability of the marbling a cut of meat contains. Some are also concerned with increasing the amount of fat dispersed among the muscles after slaughter, by infusion.

Limited research has validated that marbling contributes to the pleasure a consumer derives from eating meat, because of increased juiciness, and some real and/or imagined improvement in flavor and tenderness. At least the effect is noticeable enough that observing purchasers select meat with some attention paid to marbling.

The method meat technologists most commonly use for appraising marbling in meat is scoring. This is subjective, of course, but some have developed a high degree of repeatability—meaning they are very likely to score a specific cut the same on two different occasions—so the scoring technique has some value. Determining ether extract of the defatted muscle (external fat removed) measures total fat but not the fineness of dispersion, considered important by some. Other methods are (1) counting flakes of marbling in random marked squares on the cut surface, (2) measuring specific gravity of the defatted muscle, and (3) measuring, with a sensitive light meter, the light reflected from the cut surface of meat.

26.6 Color

Color is caused by pigments. Pigments are chemicals, which can be changed by certain environmental conditions. The meat technologist is concerned with identifying the pigments in meat and determining how feeding, preslaughter treatment, storage, light, air, curing, and other factors influence them (see also Figure 3-7, page 44).

The most preferred color of beef is often described as a bright cherry red. The USDA standards (June 1956) for the Prime grade say that the lean color must be uniform and bright, but may range from a pale red

[12] H. L. Self. *Am. Meat Inst., Proc. of the Ninth Res. Conf.*, Chicago, 1957.

to a deep blood red Veal is expected to be grayish pink in color, lamb pink, and fresh pork is normally light pink.

There is considerable color variation within species and also among muscles within a carcass, especially in the case of pork. "Two-toned" hams, with dark lean near the pelvic bone and lighter lean near the outside, are rather common

Myoglobin is the major meat pigment. Its concentration in muscles, and the degree of conversion to its chemical derivatives, are the primary factors in meat color. Normal chemical changes which occur in meat are charted in Figure 26-3.

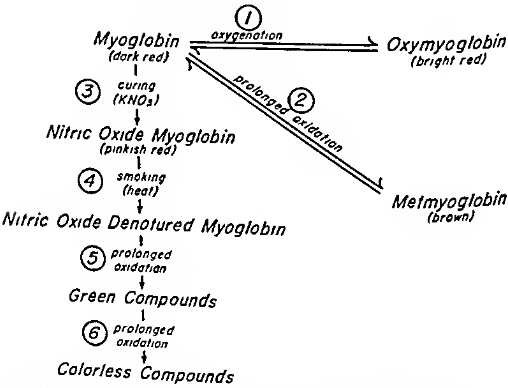


Figure 26-3. Some of the chemical changes which occur in the meat pigment, myoglobin (Adapted from B S Schweigert, *Am Meat Inst*, *Proceedings of the Eighth Research Conference*, 1956)

Reaction 1 represents the brightening of fresh meat color, which normally occurs 20 to 30 minutes after cutting. Reaction 2 results only from prolonged exposure of unwrapped fresh meat to air, and results in a dark brown color. Note Reactions 1 and 2 are reversible.

During curing, potassium nitrate in the curing formula causes Reaction 3. The pinkish red color resulting is relatively unstable, but is stabilized during smoking, because of the heat. Reactions 5 and 6 usually occur only in cured meat that has been in storage a considerable time.

Reasons for variations in fresh meat color among animals within a species are not fully known. Concentration of myoglobin may be inherited to a degree. Concentration, and degree of conversion to related compounds, may be related to feeding programs, treatment before slaughter, or other factors. Some evidence[13] indicates, for example, that cattle fed a higher proportion of corn to supplement during the feeding period, or given a normal intake of grain right up to slaughter time, tend to have brighter colored beef, and that a combination of chilling and lack of feed increases the incidence of dark beef. Research[14] with hogs has given similar results.

26.7 Preservation

Most commonly used meat preservation techniques prevent spoilage by eliminating one or more of the environmental factors spoilage organisms need—water, air, warm temperature, or other factors. Canning seals out oxygen, freezing inhibits or kills the organisms, drying eliminates most of the water, and curing (Section 24.8) increases the salt concentration so most organisms cannot live. More recent preservation techniques include the use of antibiotics, which retard growth and reproduction of certain organisms, and irradiation, which kills most organisms.

Though the meat technologist is obviously concerned with the effectiveness and relative cost of these preservation techniques, there are also other considerations. Certain preservation methods may cause undesirable flavor or color, or change other quality characteristics of meat. Such changes may occur at the time of preservation or may develop during later storage (Figure 26-4).

[13] T. M. Ramsbottom *et al.*, *Dark Cutting Beef*, National Livestock and Meat Board, Chicago, 1949.
[14] R. N. Sayre *et al.*, *J. Animal Sci.* 18: 1477, 1959.

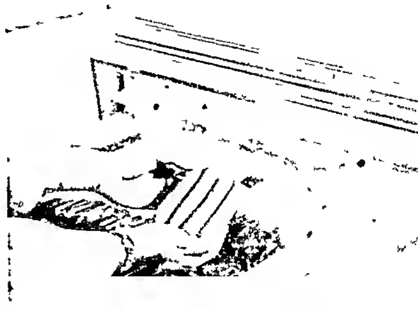


Figure 26-4. Weiners, some containing sodium ascorbate or related compounds, are held in open display coolers to determine the effect of these preservatives in maintaining quality and appearance. (Am Meat Inst. Found.)

Section 26 6 discussed the color changes which occur when meat is cured Potassium nitrate in the curing formula apparently causes the color change, salt and sugar contribute to the typical cured meat flavor These changes are considered desirable by people who like ham and bacon But, as mentioned in Section 26 4, this high salt concentration may contribute to development of a rancid aroma and flavor after prolonged storage

Freezing is probably the most satisfactory method of meat preservation at the present time Meat is usually 'sharp frozen" at about —30° F, so ice crystals formed in the meat will be small It is then stored at about 0°F Freezing and storing at these temperatures kills or inactivates nearly all spoilage organisms and inactivates the enzymes meat contains, yet does not impair flavor, color, aroma, or other quality characteristics of meat during recommended storage times If well wrapped, beef or lamb can be stored in a freezer six months or longer Four months is a practical limit for fresh pork, and two months for cured meat

Dehydration of meat for preservation is effective and satisfactory, if *freeze dehydrated* If dried by vacuum or normal air drying, undesirable flavor and texture changes occur Freeze dehydration is accomplished by drying the meat in the frozen state Special techniques cause conversion of ice crystals directly to water vapor Moisture can be reduced to two per cent, so after dehydration such meat can be stored or shipped in packages at room temperature without spoilage Rehydration can be accomplished in 15 minutes or less, before cooking

The antibiotics[15] demonstrated to be effective at low levels in meat preservation are of the tetracycline group Even these are rather ineffective, unless the meat carries relatively few organisms initially and is held at a temperature near freezing Since antibiotics *do not kill* spoilage organisms, but merely inhibit their growth and reproduction, there is a limit to the increased storage time that can be achieved

Radiation[16] of food usually involves electron beams or gamma rays, emitted from special machines These beams penetrate the food, killing certain or all organisms, depending on the dose of radiation given High, sterilizing doses or radiation damage the flavor, odor, and/or color of most foods, especially meat The flavor change, apparently involving fat and sulfur containing amino acids, is considered undesirable by most people, and is more marked in beef than in pork Radiation of fresh meat with high doses causes development of a brown color, a pink color often develops when cooked mea' is radiated for preservation

Low doses of radiation have been demonstrated to be effective in ·engthening storage time of meat, while not causing a marked change in olor or flavor Low doses kill certain of the more common kinds of

[15] C. F Niven Jr and W R Chesbro *Am Meat Inst Proc of the Eighth Res Conf* Chicago 1956

[16] W M Urbain *Am Meat Inst Found Circ 45* p 7 1958

organisms. Since antibiotics would inhibit the activity of those organisms not killed by low doses of radiation, a combination may be most effective in prolonging storage life of refrigerated meat. It is apparent that once meat is irradiated to kill organisms it must be packaged to prevent entry of additional organisms.

Another limiting factor in the use of radiation for preservation of fresh meat is that radiation does not inactivate the enzymes in meat. Hence, if radiation were used to sterilize fresh meat for extremely long storage, the enzymes would continue to function and degrade the meat structure. Therefore, the main application of radiation may be for prolonged preservation of *cooked* meat, in which enzymatic activity has been destroyed.

At the same time, prolonging storage time slightly by low radiation may allow some aging and tenderization of the meat cuts.

26.8 Specialty Meats

A rapid increase in proportion of meat sold in processed form has contributed to the growth of the science of meat technology. Space does not permit a thorough discussion of preservation techniques employed in making all kinds of sausages, wieners, and other processed meats, or the consideration given to standardization of nutrient value, flavor, color, and other factors.

Grinding meat automatically increases preservation problems since it increases surface area exposed to contamination by spoilage organisms. Whereas antibiotics applied only to the surface of meat cuts can be effective, if used in ground meat they must be mixed thoroughly and are usually effective only when used at higher levels.

Cereal products, milk products, and other nonessential materials are used in certain processed meats to increase water-holding capacity, reduce cost of production, or improve color, flavor, texture, or fat stability. Sausages produced in plants under federal inspection may contain up to three and one half per cent of these ingredients, and the moisture percentage is also controlled. Certain phosphate compounds are added to meat curing mixtures to decrease moisture loss during smoking and during cooking. Other examples could be cited to illustrate the complexity of the prepared meat field and the need for study and research aimed at producing more nutritious, more desirable, and more uniform meat products.

26.9 Meat Research Agencies

Many individual meat processors do considerable research in attempting to find ways of producing high quality and more economical products, as well as new products.

As an industry the processors financially support the research program

of the American Meat Institution Foundation, located on the campus of the University of Chicago Some of the research conducted at the foundation has been mentioned in previous sections of this chapter The foundation receives money from meat processors and others who have a stake in the meat business, to do research in meat processing, preservation, and cooking, as well as research on processing meat by products, such as livestock feed The foundation also does research on a contract basis or cooperates in research projects with other interested groups

Agricultural experiment stations in most states do considerable research in meat technology This may include evaluation of meat produced in nutrition, management, or breeding studies, or may be in the area of processing and preservation Funds for such research come from the state or federal government or as grants from private companies

The USDA also carries on some meat research projects, at the main research station at Beltsville, Maryland, at their branch stations, or in cooperation with one or more state agricultural experiment stations

Because of the importance of meat in the diets of men in the armed forces, considerable work on meat preservation, handling, and cooking is done by the Quartermaster Food and Container Institute for the Armed Forces Chicago Their research has included experimentation with freeze-dehydration of meat, to produce a product that is light, can be stored and shipped without refrigeration, and is palatable when rehydrated and cooked

They have developed tasty meat dishes in squeeze tubes, so a jet pilot flying long hours in a pressurized suit can gain nutrition and pleasure from eating meat Realization of the conditions under which many in the armed forces work, and must be fed, vividly emphasizes the task confronting this research group

27

WOOL AND MOHAIR

Wool is the most valuable by-product of meat animal production. It is by far the most used *natural animal fiber* for fabrics (other animal fibers include mohair, cashmere, and vicuna). To the consumer, it is a reliable and increasingly versatile fiber that, when woven into cloth, contributes to warmth and an attractive appearance.

Wool has been used for clothing and other fabrics for over 12,000 years. Today, essentially every wardrobe contains woolen garments, plus garments which contain wool along with some other natural fiber and/or a synthetic fiber. The average American has "consumed" about 2.5 pounds of wool each recent year (Figure 27-1).

The United States wool industry today can be described in a variety of ways—about 30 million sheep shorn each year, about 300 million pounds of "grease" wool produced annually, or about 600 mills producing about a billion dollars' worth of textiles annually.

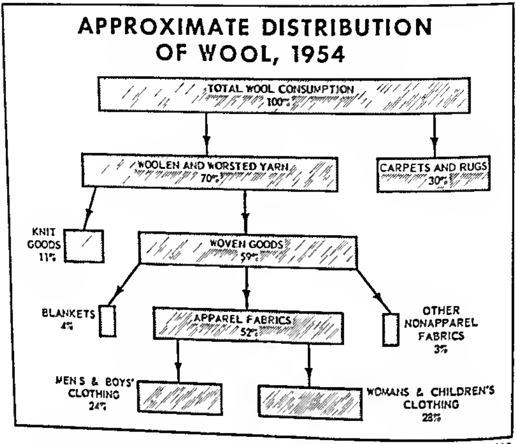
Wool as it is clipped from the sheep and before it has been cleaned is called "grease" wool. Clean wool is often called "scoured" wool.

27.1 Characteristics of Wool

A single wool fiber may be from 1/2,000 to 1/300 of an inch thick and one and one half to five or more inches long. Wool is composed primarily of amino acids, especially those containing sulfur (methionine and cystine). The manner in which the amino acids are chemically linked probably explains some of wool's unique characteristics.

Wool is elastic. It can be stretched 30 per cent, or crumpled tightly, and will rapidly recover its natural shape. This property becomes a built-in characteristic of fabric that has a high percentage of wool. It may be wrinkled, twisted, and stretched, but will regain its shape if allowed to hang overnight (Figure 27-2).

The billions of amino acid molecules in a wool fiber are apparently linked together in coiled chains which lie adjacent and which are chemically cross-linked. As a wool fiber is stretched these coils are distorted and when tension is released they return to their natural position.



USDA, AMS

Figure 27-1. Distribution of wool used in 1954. Percentages for the early 1960's are similar.

Wool has crimp. This natural wavy appearance adds to its effective elasticity, but also provides other advantages. Crimp prevents the individual fibers from lying close to each other in cloth. This produces a bulky effect, with tremendous insulation value. Depending on texture and fineness of the fiber, from 60 to 80 per cent of the volume of woolen fabric may be air.

Each wool fiber has an outer layer of flat, scalelike cells which overlap like shingles and which are covered with a thin membrane. Rain is repelled by the membrane, but water vapor can penetrate it. The protein cells in the center of the fiber absorb the moisture which may penetrate the membrane. This property allows water-soluble dye to react with the proteins so the color becomes an integral part of the fiber.

Crimp, the scales of the fiber, and the reactivity of certain of the spindle-shaped cells under the scales apparently allow the short wool fibers to adhere to each other as they are spun into a continuous strand of yarn.

Wool is strong. It is often said that a single wool fiber is stronger than steel of the same diameter.

The spiral twist of the two core sections as it is related to the natural crimp of the wool fiber (the more reactive sectian forms the outside portian of the crimp bend).

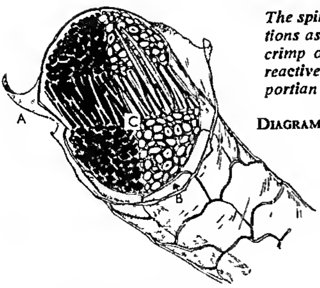


DIAGRAM OF THE WOOL FIBER SHOWING:

A) The outer, water-repelling sheath
B) The scale-cell layer
C) The twa sections of the core of spindle-shaped cells as represented by the light (less reactive) and dark (mare reactive) areas.

Schematic representation of protein chalns of woal. The chemically reactive sites firmly hold dye molecules, attract water molecules, etc.

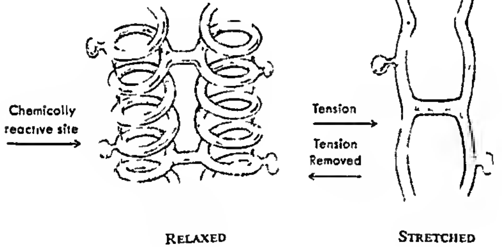


Figure 27-2. Characteristics of the wool fiber. (The Wool Bureau, Inc.)

27.2 Wonl Quality

Quality attributes in wool include fineness, length, crimp, color, strength, uniformity, and, in grease wool, percentage and kind of foreign material. Fineness is considered the most important.

The "spinning count" nnd "blood" systems used for grading wool according to fineness are given in Table 27-1. The spinning count system is the basis of present USDA grades, even though the blood system is well known and used. The grade number in the spinning count system refers to the "hanks" (560 yards per hank) of yarn that can theoretically be woven from one pound of scoured wool.

Table 27.1. Wool Grades and Specifications

U.S.D.A. Grade (March 1955)	Av. fiber diameter (microns)	Blood system grade	Breeds according to approximate wool grades*
80	17.7-19.1	Fine	Merino
70	19.2-20.5		
64	20.6-22.0		Rambouillet
62	22.1-23.4	1/2 blood	
60	23.5-24.9		Targhee Southdown
58	25.0-26.4	3/8 blood	Montadale Shropshire
56	26.5-27.8		Corriedale Hampshire Columbia
54	27.9-29.3	1/4 blood	Dorset Suffolk
50	29.4-30.9		Oxford
48	31.0-32.6		
46	32.7-34.3	Low 1/4 blood	Cheviot Romney
44	34.4-36.1	Common	Leicester
40	36.2-38.0	Braid	Cotswold
36	38.1-40.2		Lincoln

*This is not an attempt to rank breeds according to wool fineness. It is well known that there is much range within breeds and an average cannot be precisely determined. Breed listing was adapted from *Montana Agr. Exp. Sta. Circular 218* and, with permission, H. M. Briggs, *Modern Breeds of Livestock*, second edition, The Macmillan Company, New York, 1958.

Originally, the blood system of grading wool was an indicator of the fraction of Merino breeding in the animal from which the wool came. The Merino breed produces fine, high quality wool, and fineness is highly inherited. Since the development of other distinct breeds, the original blood system has simply been adapted to describe relative fineness.

Fineness is important because it allows the spinning of a finer yarn, tighter weaving of cloth, and production of lighter fabrics and garments.

Fine wool often has more crimp, too, another attribute of wool quality. Crimp helps individual fibers cling together during spinning, so a strong yarn can be woven with fewer fibers lying parallel. Crimp, then, also contributes to lighter weight garments and more efficient wool use. Fine wool often has 15 or more crimp per inch; coarser wool has less. Wool from the back usually has more crimp than wool from the thigh.

Length of fiber is a quality factor. Though fine fleeces usually have

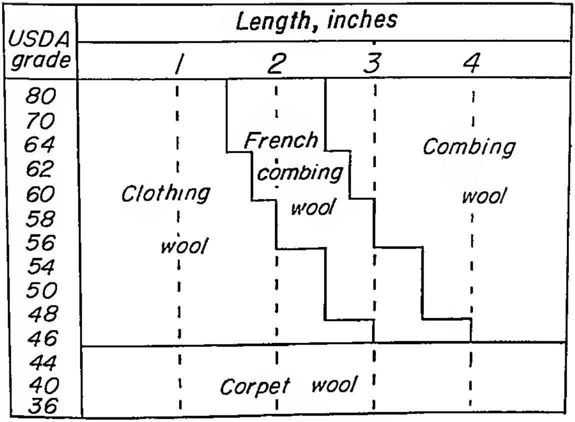


Figure 27-3. Length designations often used for wool, according to fineness. (AMS, USDA)

relatively short fibers, the longer the better. The reason for this is apparent too, in spinning a strand of strong yarn.

Though wool length is easily measured in inches, a variety of special terms are commonly used in the wool industry to describe relative length, according to the way it can be processed. These are summarized in Figure 27-3.

"Combing" wool is long enough that regular combing machines can sort and straighten the fibers to make "worsted" yarn, which is smooth and used for light, high quality cloth. This wool is also called "staple length." "French combing" wool is handled essentially the same as regular combing wool, except that special combing machines have to be used because the fibers are a bit short. "Clothing" wool is not long enough to be handled even by special combing machines. This wool, therefore, can only be carded and is destined for use in tweeds and other fuzzy fabrics. Extremely short wool, from young lambs or extremely old ewes, is often called "scouring" wool. Since it cannot be effectively combed, it may be used for felt or similar materials.

It is apparent from Figure 27-3 that fine wool can be shorter and still be processed in regular combing machines.

Amount of foreign material and yolk in the wool is considered in appraisal of grease wool. It is not uncommon for a 10 pound, fine wool fleece to yield but 4.5 pounds of scoured wool, meaning it contained 5.5 pounds of yolk and foreign material. In other words the shrinkage on scouring was 55 per cent.

Fine wool fleeces normally carry more foreign material than medium or coarse fleeces. Many fine wool sheep are raised in arid sections of the country where considerable dust blows and, since fine wool contains more yolk, the dirt sticks better. Medium wool from the Midwest normally shrinks 45 to 53 per cent.

Traditionally, wool quality has been appraised for sale purposes by experienced buyers and sellers, who rather accurately estimate fineness, length, shrinkage, and other quality characteristics. In recent years the practice of "coring" bags of wool and subjecting core samples to objective measurements for appraisal purposes has increased. A micrometer is used to measure fiber diameter and a special machine actually scours the sample to determine per cent shrinkage.

27.3 Wool Processing

At the mill each fleece is pulled apart and sections of the fleece are sorted according to fineness, length, and other characteristics. Fleeces are purchased by processors according to these factors, of course, but there is usually some variation within a fleece.

All wool is washed in several tanks of hot, soapy water, rinsed, and dried. This is called scouring, and removes grease and most other foreign matter. Lanolin is recovered from the washings, purified, and sold as a base for face creams and similar items.

Next the dried wool passes to carding machines where revolving cylinders covered with fine wire teeth remove burrs, straw, and similar matter, and straighten and comb the wool into a thin veil or web.

From this point on, processing depends on diameter and length of wool, and whether "woolen" or "worsted" yarn is to be made. Woolen yarn is generally made of shorter and thicker fibers (clothing wool), that may lie in all directions, to produce thicker, fuzzier fabrics, such as tweeds. Worsted fabrics, such as gabardine, are made from yarns of longer, finer fibers (combing wool), so the fabrics will be lighter and have a harder, smoother finish. Slightly over half of the apparel wool in this country is used in worsted fabrics.

For the spinning of woolen yarn, the web from the carding machine is simply split into thin, soft strands called roving. For worsted yarn, however, the fine web must go through further sorting, combing, and straightening of fibers until a very thin, smooth strand of worsted roving can be obtained.

Spinning of roving into yarn is accomplished by mechanically twisting the roving. The machines then wind the spun yarn onto spools. From here on, yarn may be utilized in a variety of ways. Most, of course, is knitted or woven into fabric.

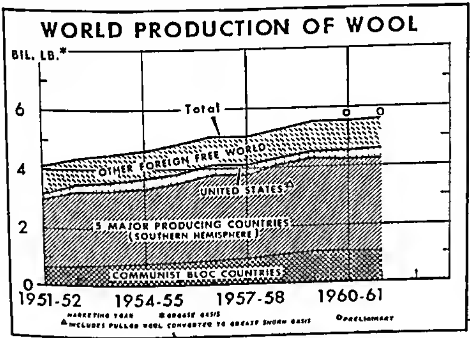
Wool may be dyed in any stage of manufacturing, immediately after scouring, in the yarn stage, or as finished fabric.

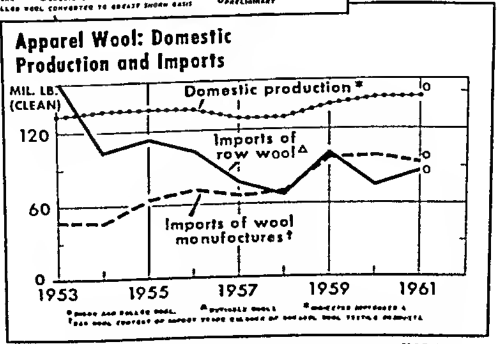
27.4 World Production of Wool

Because 65 to 75 per cent of the wool processed in the United States is imported, a consideration of world production[1] is important (Figure 27-4). Clean wool production in recent years has been about three billion pounds (from almost six billion pounds of grease wool), which averages about one pound per person. Production in the major countries is given in the Appendix. Australia, New Zealand, The Union of South Africa, Argentina, and Uruguay are major producing and exporting countries.

[1] AMS, USDA, *The Wool Situation*, August 1961 and October 1961.

Figure 27-4. The United States and world production of wool on the left. Domestic production compared with imports on the rigbt.





USDA, AMS

About 80 per cent of the world production is apparel wool—used for clothing and similar fabric, and designated in Figure 27-3 as combing, French combing, or clothing wool The remainder is carpet wool, used for rugs, carpet padding and similar materials The five major exporting countries in the southern hemisphere, mentioned above, produce about 70 per cent of the apparel wool Another 20 per cent is produced in the United States, Great Britain, Canada, France, and Germany Major sources of carpet wool are the U S S R , India, China, and the countries surrounding the eastern Mediterranean

Because labor and other production costs are so much lower in most southern hemisphere countries, wool can be produced cheaply enough that exporters in those countries can pay the United States import duties and still compete in price with wool produced in the United States The import duties finance incentive payments made to U S wool producers (Section 27 5)

27.5 Domestic Production and Marketing of Wool

Most wool is shorn in the spring, and since shorn wool represents about 80 per cent of total production, the supply is certainly seasonal The remaining 20 per cent is pulled wool, pulled from pelts of slaughtered sheep and lambs

Though production is seasonal, wool is not a perishable product if well handled, so processing mills can operate at a fairly uniform rate during the year Also, processors can even out the supply by importing relatively more in the fall months, when wool is being shorn in the southern hemisphere

The average fleece of grease wool in the United States weighs a bit over eight pounds In certain western states, such as Montana, Idaho, and Wyoming, where wool production is a major enterprise and selection for heavy fleeces of good quality wool has been more intensive and more effective, average fleece weights often exceed 10 pounds Appendix Table 6 lists grease wool production by states and average fleece weights for recent years

Expert shearers, using power operated clippers, can shear a ewe or lamb in a few minutes (Figure 27-5) The fleece is usually tied with paper twine, with the inside of the fleece out for better appearance, and packed in large bags

Much of the wool produced in the United States is sold through producer owned cooperatives, often called "wool pools" Such cooperatives have operated effectively for many years in Texas and other western states where wool production has long been a major enterprise Similar cooperatives have developed in most other wool producing states Some handle much of the production of several states

Figure 27-5. Expert sheep shearers are rare, and are in great demand during the spring months. (Iowa State University)

The advantages of a wool marketing cooperative are apparent, especially in areas where wool production may be a sideline enterprise on many farms. Few producers are able to keep abreast of market prices, especially since they sell wool but once a year. Most are not a good judge of grade or shrinkage, so are not capable of dealing effectively with a buyer. Also, few have storage facilities and know-how, so if dependent on direct selling would need to sell at shearing time when supply is high and prices are low.

Formation of a marketing cooperative allows employment of a wool specialist who can appraise wool and keep abreast of supply and price trends. It allows provision of central storage facilities and sorting of wool into quality groups before it is offered for sale. It also creates a concentrated supply, attracting buyers and creating producer bargaining power.

Producers usually consign their wool to the cooperative, which makes partial payment and records the amount of each grade delivered. The wool is then stored; each grade is marketed at the time prices appear best. Each producer is then paid the balance due him, minus the costs of operation. Some cooperatives also buy wool on a cash basis from producers, hoping, of course, to make a profit.

Some wool is still marketed through a regular system of private dealers and brokers, who sell to larger brokers or directly to processors.

Boston is the center of wool marketing activity in the United States. Domestic and imported wool is sold at auction or by private treaty. Boston prices are often the basis of trading in most sections of the country. The Boston market probably developed because of the early settling of New England, development of the wool processing industry there, and shipment of wool into the Boston harbor. In recent years, however, lower labor costs in the southern states and development of many southern ports has caused considerable shifting of mills to the South.

The National Wool Act of 1954 (which has been amended several times since) established an incentive payment plan to encourage wool production in the United States An average "incentive level" price for grease wool is established each year by the Secretary of Agriculture Wool is sold by each producer through regular channels, and the average sale price for the year is then calculated

The percentage that the "incentive level" price exceeds the national average sale price is then used to calculate the payment to be paid each producer In the 1960 marketing year (beginning April 1) the incentive level price was set at 62 cents per pound and the average price received by farmers was 42 cents per pound[2] Since 62 cents exceeds 42 cents by 47.6 per cent, every producer who filed a claim was given an incentive payment of 47.6 per cent of his sale price on wool he sold during the year Therefore, a producer who sold high quality, clean wool for a high price received a higher incentive payment than one who sold low quality, heavy shrinking wool for a low price This program is one of the few governmental payment programs which provides a *high incentive* for producing a good quality product Similar payments are made for wool carried by lambs slaughtered

27.6 Merchandising Wool and Woolens

In 1960[3] there were about 13 times as many pounds of man-made, synthetic fiber produced in the United States as clean wool Rapid technological development in the 1930's and 1940's in the production of synthetic fibers caused a rather sharp drop in demand for wool The drop was interrupted by demands of World War II, but the full impact of synthetic fibers was then felt after the war

Not only does United States wool compete with synthetic fibers, it also competes with other natural fibers, such as cotton and silk, and imported wool

Since many synthetic fibers are cheaper than wool, and because there was a scarcity of wool during World War II, garment manufacturers did an effective advertising job in convincing the American public that non wool garments were entirely satisfactory, and in some cases preferred

In recent years, however, there has been considerable us of wool *in combination* with other fibers A large percentage of wool is now used in this type of fabric

Because wool is a stable fiber of long standing and good reputation, there is a natural tendency for apparel manufacturers to advertise garments containing any percentage of wool as "woolens" The Wool Products Labelling Act of 1940, however, requires that all products containing wool,

[2] AMS USDA, *The Wool Situation* August 1961
[3] *Ibid*

except upholstery and floor coverings, bear a label showing the percentage of the total fiber weight that is wool, and the percentage of each other fiber present. "Virgin" or "new" wool is used on labels to describe only wool that has never been formerly used and has not been reworked in any way.

Merits of wool as a fiber, alone in fabrics or in combination with other fibers, have caused garment manufacturers to promote wool and wool products aggressively. The Wool Bureau, Inc., of New York and Los Angeles, is an industry effort in wool and wool product promotion. It sponsors national advertising, helps individual companies with advertising of woolens, and provides considerable educational material on wool.

Producers, too, have contributed to the promotional efforts. Referendums of wool producers have voted to permit deductions from wool incentive payments, mentioned earlier, for the promotion of lamb and wool. Deductions may be as high as one cent per pound for shorn wool marketed and five cents per pound of lamb (unshorn) marketed for slaughter. The money is turned over to the American Sheep Producers Council, Inc., for administration of the promotional efforts.

The Women's Auxiliary of the National Wool Growers Association, and the Wool Bureau, Inc., have sponsored annual "Make It Yourself With Wool" contests nationally and in many states, further promoting wool use.

27.7 Mohair

Mohair is the fleece of the Angora goat. It is pure white, grows in ringlets, and the fibers after a year's growth may be as long as ten inches (though most angora goats in the southern United States and other warm climates are clipped twice yearly). The fibers are smooth, so lack the felting property of wool. In diameter, the fibers are intermediate between fine and coarse wool.

Most of the mohair is produced in Turkey, South Africa, and the southwestern United States—especially Texas. (See Appendix Tables 8 and 9.)

Mohair excels in luster, durability, and affinity for fast dyes, so it is used in goods of fine quality that are subjected to hard usage. Mohair as it comes from the animal usually contains 10 to 30 per cent short undercoat fibers which are chalky and dull. For finer mohair fabrics these fibers must first be removed by combing.

Much of the previous discussion on wool in this chapter also pertains to mohair—marketing, processing, incentive payments, etc. Of course, minor differences exist which cannot be discussed here.

28

THE BUSINESS OF DAIRYING

Dairy farming is a business, profit is the motive A dairyman ordinarily expects a monetary return for labor, capital, home-raised feed, management ability, and the risk he assumes The decision to enter, or stay in, the business of dairy farming should be based on long term expectations of return for these resources

This chapter is devoted to some of the factors which influence the profitability of dairying It includes discussions of location, size, investment needed, labor, feed, type of product desired, and other factors

It may be worthwhile to list some of the advantages and disadvantages of dairying, as a livestock operation Chapter 10 presented some reasons why a livestock feeding operation might be practical Part C of Chapter 1 is devoted to a more detailed discussion of livestock adaptation and comparison of species in this respect Most items discussed are relevant to dairying A few considerations specific to dairying follow

1 Dairying provides a market for family or hired labor, on a uniform basis The labor needs are not seasonal
2 High quality labor is necessary
3 Dairying provides a continuous income Milk sold is usually paid for biweekly or monthly
4 Much roughage can be marketed through dairy cattle Young stock grows mostly on roughage, and milking cows can utilize large quantities, if it is good quality This makes dairying especially adapted to pasture and forage areas
5 Milk is a relatively perishable product, compared to fed hogs, steers, or lambs, or to wool, corn, oats, and other agricultural products This means that it must be moved to the consumer rapidly, and greater care must be taken in handling and preservation
6 Milk is a highly desired and respected food It contains needed nutrients, and is often described as "nature's most nearly perfect food" This lends stability to the demand for the product
7 The dairy business is one of the most stable of livestock enterprises, from an economic standpoint Milk production does not go up and down in regular long term cycles as is true for beef, lamb, and pork Also since dairy products compete less with other animal products which may be in surplus, prices received for milk are more stable (Figure 28 1)

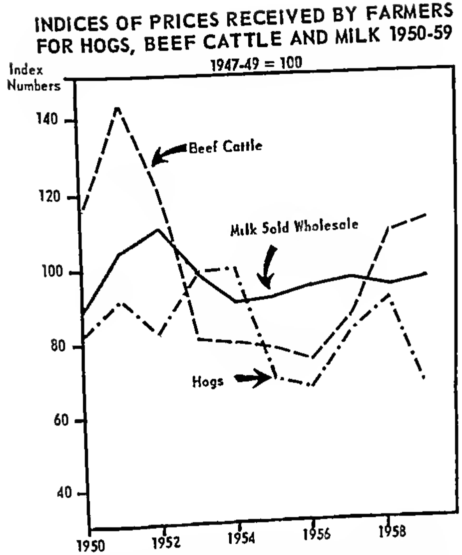


Figure 28-1. The price of milk has been steadier than the price of beef cattle or hogs. This may mean less risk and more confident planning to some farmers. (National Milk Producers Federation)

8. Energy and protein in grains and forages are converted more efficiently to human food when milk is produced than when meat is the product.

Dairying has become increasingly specialized. On most farms where dairy cows are kept, the dairy herd is a major enterprise and contributes a major portion of the farm income. Dairying as a side-line enterprise is practiced on fewer farms. Some of the reasons for these changes are discussed in later sections.

In the 18 years prior to 1962 the number of dairy cows on farms dropped about 30 per cent while production per cow rose about 55 per cent, causing a net increase in total milk production (Figure 28-2). These figures reflect specialization. More efficient dairymen, who do a better job of selecting and managing dairy cattle, are producing a higher proportion of the milk. Less efficient dairymen are producing less of the milk; some are leaving the business.

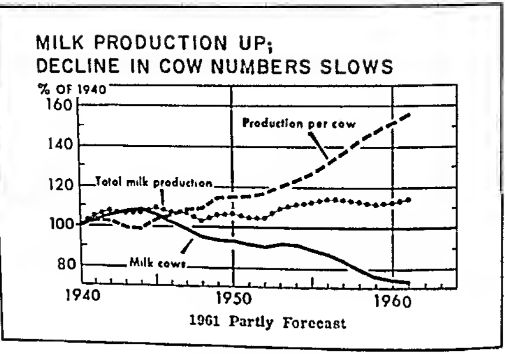


Figure 28 2 Trends in dairying The cows being kept for milking herds are much more efficient than those formerly kept How much of this increased production per cow is genetic and how much is caused by improved feeding and management?

28 1 Location

What is the best location for a dairy farm? This is influenced by markets, feed supply, labor, and perhaps climate

Traditionally, closeness to a market—consumers—has been the major consideration in establishing a dairy farm This is because milk is relatively perishable compared to other foods and, because it contains so much water, transportation costs are high

Location is *less important* today, in the latter half of the twentieth century, as processing techniques have made milk and milk products less perishable and as transportation has rapidly improved Developments in condensing, drying, freezing, and concentrating milk and milk products may, in time, make proximity to the consumer of *minor* concern in dairy farm location

Because of many federal regulations concerning milk markets and marketing mere proximity to a large population of consumers does not necessarily mean a profitable market exists for milk See Chapter 31 for a more thorough discussion of markets

Ample feed supply is essential for dairying Dairy cows need a lot of energy, and can effectively use large quantities of roughage, which is

usually an economical energy feed. Roughages must be grown fairly close to the dairy (Figure 28-3); they are bulky and expensive to transport. Considerable grain is also needed for high producing herds. As closeness to a market becomes less important in location of dairy farms, more attention can be paid to feed supply.

On a majority of dairy farms the farm family supplies most of the labor, perhaps supplemented with hired labor which also helps with other farming operations. Large, specialized units of several hundred cows or more, however, are primarily dependent on hired labor. *Cost of labor* varies considerably, according to wage rates and types of industries in the community, even though labor is somewhat mobile.

Climate probably has more of an influence on feed supply than on the productivity of dairy cows, as long as the herd is well managed. All popular breeds of dairy cattle have performed well in Alaska, if adequate shelter is provided. In the South, ample shade and water on pasture apparently make dairying a practical enterprise. There are some influences of temperature and humidity which a dairy farmer must take into account in management. These are discussed briefly in Chapters 12 and 30.

28.2 Size

There has been a marked trend toward larger, more specialized dairy farming units, especially since World War II. Dairying requires expensive equipment to meet sanitation requirements and hold down labor needs, and also considerable knowledge and skill. Therefore a dairy farm enterprise must be large enough to utilize the equipment and skill, and hold down per unit cost of production.

Figure 28-3. Irrigation is necessary to provide ample forage for this high producing Jersey herd in Texas. (The American Jersey Cattle Club)

Figure 10 1 illustrated that farm wage rates have increased faster than power and machinery costs Because of this and because labor is a *major* portion of the costs in dairying, there has been great incentive to improve labor efficiency as much as possible In some cases, mechanization has been necessary in order for dairy farming to be attractive to farm boys and hired labor, relative to feeding operations which utilize self-feeders and automatic or semiautomatic feeding equipment "Herringbone" milking parlors, equipped with milkers which route the milk through pipes to stainless steel bulk tanks, are an example Such facilities are expensive but make the operation more efficient, if it is large enough

Certain equipment needs have been imposed by sanitation ordinances and market policies In the current decade, for example, many dairymen have been forced to either quit selling milk or to install bulk handling equipment because their market will handle only bulk milk This is further incentive for large size in dairy enterprises

Few people would consider entering dairying today unless they could plan on a herd of 50 or more cows, and some feel a minimum of under 200 cows is not realistic Recognize that expansion beyond 50 cows often means much dependence on hired labor This, then, may dictate using two "shifts" of labor, feasible only if both "shifts" are kept busy So expansion beyond a certain point may be economically possible only if great expansion is made Number of cows needed for an efficient operation depends, of course, on volume of milk produced per cow

Minimum size depends on many factors A young man entering dairying must consider not only the factors obvious today, but those that may be present during the next 40 years He must be sensitive to changes in equipment needs, labor costs, and other factors which influence efficiency and profit in a dairy operation

The decision to milk cows is not an annual or a seasonal decision, as may be true in certain feeding operations Because of expensive equipment, a dairyman is either "in" or "out" The decision to milk cows must be accompanied by (1) the intention of dairying for a span of years and (2) a decision to milk enough cows and produce enough milk to be efficient

28.3 Investment

The previous section implied that a large investment is needed for an efficient dairy enterprise Capital is needed for land and buildings, cows, feed, equipment, and operating expenses (Figure 28 4)

Relatively permanent investments in land and buildings can be amortized over many years Long term mortgages can usually supply much of these capital needs at relatively reasonable interest rates The dairyman doesn't need to repay this kind of capital the first year, 30 or 40 year loans are not uncommon

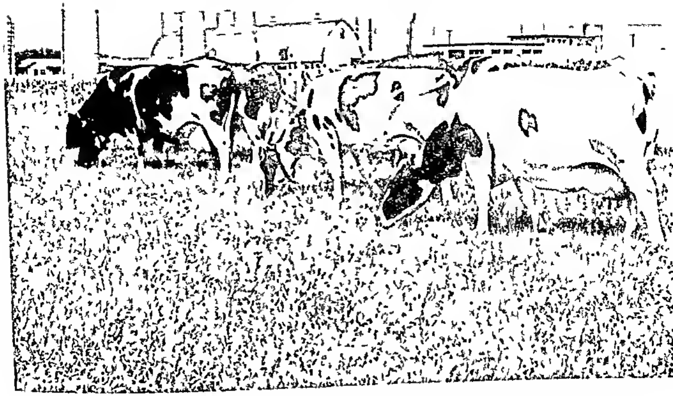


Figure 28-4. Much investment is required for producing top quality milk efficiently. Dairying must therefore be a long-term enterprise on most farms (The Holstein-Friesian Assn of America)

Dairying on rented land presents many problems. Most landlords are not willing to provide buildings and permanent equipment needed because of the temporary nature of rental contracts and because only a small percentage of renters want to milk cows. Some renters, therefore, have built portable milking parlors that are satisfactory if other shelter for "loose housing" is available. Certain portable milking parlors may not meet sanitation requirements of some markets.

Cows are a major investment. Money is needed for buying or raising replacement heifers. Credit can usually be obtained for partial financing of a herd of cows, but bear in mind that a cow has a limited life, contrasted to real estate. Loans for cows are usually for a shorter time—a few years —and at a higher interest rate because the lender assumes more risk.

Feed accounts for 50 to 60 per cent of the costs in milk production. Most feed is raised on the farm, in typical dairy operations, but still represents considerable investment. Costs involved in raising and harvesting the feed are not repaid until the feed is fed to the herd and the milk is sold. Though purchased supplements represent a small proportion of feed costs on most dairy farms, the outlay of cash is significant for a large herd

Generalizations on costs of buildings and equipment needed for profitable dairying certainly do not apply to every operation. However, for a 50-cow unit it would be difficult to provide a four-stall milking parlor, milkers, cooler, tank, and accessory equipment for less than $8,000. In most cases the cost would be higher. This does not include housing, feed handling equipment, and other such necessary items

Money for general operating costs—veterinary expenses, equipment repairs, power, and other such items—can be significant in a large opera-

tion At least they seem significant when combined with the living expenses of the farm family (see Section 1 1)

A business must provide a return on investment, as well as return for labor, management ability, and risk, in order to be fully satisfactory. The income from dairying is relatively unique, in that it is *continuous.* Milk is picked up daily or on alternate days and payment is usually made biweekly or monthly. Also, the income from dairying begins fairly soon after the business begins This is good in that such income can be used for general operating costs and family living expenses.

The term "quick income" associated with dairying may erroneously imply that the investment in the operation can be of short duration—that the "quick income" will retire the debts and mortgages in a short time. Such is not the case. In fact, investment in animals and equipment may need to be for a *longer* time than is true for cattle, lamb, or hog feeding.

28.4 Labor

Since labor represents a higher proportion of production costs in dairying than in most other livestock operations, it is important to manage the labor for top efficiency.

Labor on a dairy farm must be high quality. A worker must be alert. Sanitation is important. Udder infections must be detected, if they exist, and care exercised to prevent spreading infections among cows. Equipment must be cleaned, udders washed, and many other precautions taken to insure a high quality product.

Labor needs for dairying are *continuous.* They are not seasonal. This may be an advantage or disadvantage, depending on the other components of the farming operation. Dairy herds can provide a good outlet for family labor, because labor needs *are* continuous.

Figure 28-5. Milking parlors contribute to efficient use of labor in dairying. (Babson Bros. Co)

Though cows are milked twice every day, good labor management can make dairying a less confining business. A number of research studies have shown that milk production, on the average, is not significantly reduced by milking at 10 and 14 hour intervals. A dairyman may milk, for example, at 7 a.m. and 5 p.m. instead of 6 a.m. and 6 p.m. Further shifting of the interval may not be satisfactory, however, especially with high producing cows.

In a large dairy operation labor can be rotated, in a variety of ways, to make the job as attractive as most others. Some large dairies that milk several hundred cows employ two "shifts" of labor. One shift may work from 3 a.m. to 11 a.m., the second from 3 p.m. to 11 p.m. Some even operate three shifts and milk "around the clock." This illustrates another advantage of large size.

It is apparent that expensive equipment and automation cannot reduce labor needs in dairying as much as in feeding operations with lambs, hogs, or beef cattle. But there is opportunity for a good manager to use labor more efficiently in dairying than has been traditionally done, and to make dairying more attractive to labor.

28.5 Feed

Chapter 7 is devoted to ruminant nutrition, and presents most of the principles involved in feeding growing heifers and mature dairy cattle. Tables 7-1 and 7-2 give examples of the nutritive requirements of dairy cattle according to stage of production. Sections 7.6 and 7.7 present some considerations peculiar to feeding dairy cattle, and Section 7.7 gives an example of a complete ration for dairy cows. Because calves are functionally non-ruminants until four to six weeks of age, they are discussed in Chapter 6, Nutrition of Non-ruminants.

Supply of feed was mentioned in Section 28.1 as a factor in dairy farm location, and in Sectinn 28.3 it was stated that in most dairy operations feed represents 50 to 60 per cent of production costs.

Roughage—pasture, hay, silage, and soilage—is the backbone of most feeding systems for cows. Good quality roughage is invariably a cheaper energy source than grain and also supplies most of the protein. Roughage *must* be high quality for efficient and maximum production. There is a limit to the capacity of a cow's digestive system. If roughage is low in quality and therefore poorly digested, a cow cannot eat enough to supply the energy she needs for maximum production. Also, low quality roughage is usually less palatable, so a cow may even *eat less* than she could.

Quality of roughage available is the key to formulation of concentrate mixtures (Section 7.6). Low quality roughage must be supplemented with more concentrates, higher in protein and minerals. Top quality roughages sometimes need be supplemented only with home-grown grain.

Because roughage is so important in feeding dairy herds, managing and harvesting the roughage supply deserves consideration Strip grazing—where cows are restricted to a strip of pasture sufficient for one or a few days—makes much better use of pasture Confining the cows to dry lot and feeding the pasture forage freshly chopped allows even more efficient use of the forage, but cost of chopping and hauling must be considered to determine if the practice is feasible

It may be more practical to harvest the entire crop of forage as silage and/or hay, cutting at the best stage of growth, then feeding it daily to the cows in dry lot This would take advantage of the increased efficiency in forage production and utilization, compared to pasturing, while also eliminating the need for daily chopping of fresh forage

28 6 Type of Product

Fluid milk is the common product of most commercial dairy farms In 1960, 84 per cent of the milk produced on farms was sold as whole milk, even though a substantial amount of this was converted to other products after reaching the plant Thirty years earlier only 35 per cent was sold as whole milk, most of the remainder was separated, the cream sold, and the skim milk fed on the farm [1]

A dairy farmer must be alert to the kind of product consumers desire He should watch consumption trends, understand the basis for fluid milk pricing mechanisms, and be prepared to change his product, when possible, to meet consumer desires

Historically, most whole milk pricing systems have been on a hundred weight basis according to the percentage of butterfat At one time, when butterfat was by far the most valuable component of whole milk, the price differential based on the percentage of butterfat was large In recent years the differential has decreased Butterfat is valuable, but not as valuable as formerly, relative to other milk components

Several reasons for this shift are obvious Per capita butter consumption declined over 50 per cent in the 20 years prior to 1961 There was a marked shift to spreads containing plant fats or lower-cost animal fats Per capita consumption of cheese (made largely from skim milk) increased over 50 per cent More nonfat dry milk is being used in processed foods as well as for direct home consumption People are drinking more skim milk Emphasis on low calorie, high protein diets to prevent obesity and improve health has no doubt encouraged this decrease in butterfat consumption and increase in consumption of nonfat milk products

Because of the shift in consumer demand to the nonfat portion of milk and less demand for butterfat, pricing mechanisms for whole milk may, in time, be based on the percentage of "solids-not fat" (which includes pro-

[1] ERS USDA *Dairy Situation* April 1961

Table 28-1. Approximate Percentage Composition of Milk Produced by Dairy Breeds, and by Areas

Breed	Water	Fat	Solids[1] (non-fat)	Protein	Lactose (carbo.)	Ash (minerals)
Ayrshire	86.9	4.1	8.98	3.6	4.7	0.68
Brown Swiss	86.6	4.0	9.33	3.6	5.0	0.73
Guernsey	85.1	4.9	9.64	4.0	4.9	0.74
Holstein	87.5	3.5	8.88	3.4	4.8	0.68
Jersey	85.3	5.2	9.50	3.9	4.9	0.70
Market Milk[2]						
Pacific Northwest		4.0				
Northern Plains		3.55				
East North Central		3.7				
New England		3.9				
Gulf Area		4.0				

[1] Often abbreviated as SNF: total of protein, lactose, and ash.
[2] Approximate averages for milk received at federal order markets in these areas during 1960. Supp. for 1960 to *Sta Bull. 248*, Dairy Division, AMS, USDA.

tein, carbohydrates, and minerals) as well as fat. Certain markets are using such a system now (see Section 31.6). Of interest in this discussion is the average composition of milk produced by cows of major dairy breeds, and the average percentage of fat in milk produced in certain sections of the country (Table 28-1).

Other characteristics of milk are important to the consumer. Flavor of milk can be altered by feed and management practices (see Chapter 30). Color of milk may vary among animals, and certainly does among breeds. Guernsey milk, for example, has a richer yellow color, preferred by some people and highly promoted by those who produce and sell Guernsey milk. The reason for this difference in color is also explained in Chapter 30.

28.7 Replacement Heifers

To maintain herd size, on the average farm, enough young heifers need to be available each year to replace about 20 per cent of the milking herd.

In DHIA (Dairy Herd Improvement Association) herds, where considerable culling is done, the annual replacement rate is about 25 per cent. On some farms, where stock is selected with greater care and selected heifers have a longer productive lifetime, the need for replacements may be somewhat lower.

Since heifers often do not enter the milking herd until 26 to 30 months of age, and a dairyman may wish to save most heifers until they are old enough to do some visual culling, the above figures indicate that he may need to *feed and maintain continually* almost *two thirds* as many young heifers—of all ages—as he has mature cows in the herd. This represents

Because roughage is so important in feeding dairy herds, managing and harvesting the roughage supply deserves consideration Strip grazing—where cows are restricted to a strip of pasture sufficient for one or a few days—makes much better use of pasture Confining the cows to dry lot and feeding the pasture forage freshly chopped allows even more efficient use of the forage, but cost of chopping and hauling must be considered to determine if the practice is feasible

It may be more practical to harvest the entire crop of forage as silage and/or hay, cutting at the best stage of growth, then feeding it daily to the cows in dry lot This would take advantage of the increased efficiency in forage production and utilization, compared to pasturing, while also eliminating the need for daily chopping of fresh forage

28 6 Type of Product

Fluid milk is the common product of most commercial dairy farms In 1960, 84 per cent of the milk produced on farms was sold as whole milk, even though a substantial amount of this was converted to other products after reaching the plant Thirty years earlier only 35 per cent was sold as whole milk, most of the remainder was separated, the cream sold, and the skim milk fed on the farm [1]

A dairy farmer must be alert to the kind of product consumers desire He should watch consumption trends understand the basis for fluid milk pricing mechanisms, and be prepared to change his product, when possible, to meet consumer desires

Historically, most whole milk pricing systems have been on a hundredweight basis according to the percentage of butterfat At one time, when butterfat was by far the most valuable component of whole milk, the price differential based on the percentage of butterfat was large In recent years the differential has decreased Butterfat is valuable, but not as valuable as formerly, relative to other milk components

Several reasons for this shift are obvious Per capita butter consumption declined over 50 per cent in the 20 years prior to 1961 There was a marked shift to spreads containing plant fats or lower cost animal fats Per capita consumption of cheese (made largely from skim milk) increased over 50 per cent More nonfat dry milk is being used in processed foods as well as for direct home consumption People are drinking more skim milk Emphasis on low calorie high protein diets to prevent obesity and improve health has no doubt encouraged this decrease in butterfat consumption and increase in consumption of nonfat milk products

Because of the shift in consumer demand to the nonfat portion of milk and less demand for butterfat pricing mechanisms for whole milk may, in time, be based on the percentage of solids not fat' (which includes pro-

[1] ERS USDA *Dairy Situation* April 1961

Table 28-1. Approximate Percentage Composition of Milk Produced by Dairy Breeds, and by Areas

Breed	Water	Fat	Solids[1] (non-fat)	Protein	Lactose (carbo.)	Ash (minerals)
Ayrshire	86.9	4.1	8.98	3.6	4.7	0.68
Brown Swiss	86.6	4.0	9.33	3.6	5.0	0.73
Guernsey	85.1	4.9	9.64	4.0	4.9	0.74
Holstein	87.5	3.5	8.88	3.4	4.8	0.68
Jersey	85.3	5.2	9.50	3.9	4.9	0.70
Market Milk[2]						
Pacific Northwest		4.0				
Northern Plains		3.55				
East North Central		3.7				
New England		3.9				
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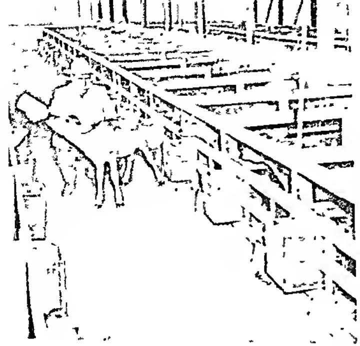

Figure 28-6. Cost of raising replacement heifers is significant because of both feed and labor. These Jersey calves on a large dairy farm in Texas are bottle-fed the first few weeks. (The American Jersey Cattle Club)

a tremendous expense, and a lot of feed is used on a dairy farm for animals other than those in milk. The recommended practice of calving heifers at 24 months would reduce needed replacement numbers, permit more rigid culling, and/or facilitate herd expansion (Figure 28-6).

If the dairyman is trying to increase the size of his herd, he must raise more heifers or else buy some. How many heifers can he raise in a herd under normal conditions? New England studies indicate only about 35 heifers can be raised per year from 100 cows. Some cows do not calve; some have a reproduction interval longer than 12 months. Some calves die, at birth or early in life. It is obvious, then, that increasing herd size by raising replacements is a slow process, and also does not allow much *selection* to be practiced. Nearly all would need to be saved, regardless of quality.

Is it best to *raise* replacement heifers, or *buy* them? As with other management problems, the answer depends on conditions. Those who raise their own do so because, "Homegrown heifers cost less money," "More profitable use of land and labor," "Less disease in my herd," and for other reasons. One important reason is that farmers who raise their own heifers may do a better job of choosing the best ones. Especially if the herd is on DHIA or other record programs, the dairyman knows which heifers are out of the high producing cows. He doesn't have to depend solely on visual appraisal.

It is possible, of course, that heifers might be purchased from a dairyman on a record program. But if the seller is trying to maintain his herd size, he will no doubt keep the best 60 to 70 per cent of his own raising and will offer the *remainder* for sale to you.

Replacement heifers on a farm represent a sizable investment. There

are situations in which capital is limited and the capital available can be more wisely used for mature cows in milk than for maintaining heifers. Feed, space, and labor might also be limited.

At the same time there are some farmers who can profitably raise replacement heifers. A certain farmer, for example, may not have milking facilities or an available market, but ample forage and other feed, as well as skill and experience in raising heifers. He might purchase heifer calves, raise them to breeding age, artificially inseminate, and sell them just before they calve. In some cases, such farmers raise replacement heifers for large dairies on a contract basis.

28.8 The Bull Calves

As artificial insemination becomes more popular, the price of the few best bulls goes higher; mediocre and poor bulls are of little value for breeding. Therefore, most bull calves on dairy farms are more profitably sold for *meat.*

The dairyman has several alternatives for handling such calves—"bob veal," "veal," or growing for a regular feeding program. Bob veal or "wet calves" are usually defined as slaughter calves under three weeks of age. The flesh is very watery and has little flavor, but can be used for certain prepared meat items. Sale price is usually low, but normally enough to justify the trip to the market.

Veal is defined as a slaughter calf between three weeks and three months of age. The profitability of feeding calves to this age depends, of course, on (1) price of bob veal, (2) price of veal, (3) cost of raising the calf, and (4) birth weight of the calf. The main feed for such calves is usually milk, so the third item above depends primarily on the cost of milk. Table 28-2 illustrates the value of milk fed to such calves.

Table 28-2. Value of Milk per Hundredweight When Fed to Calves Until They Weigh 180 Pounds*

Birth weight	Bob veal price per lb.	Veal price per lb. $ .20	.30	.40	Lbs. milk needed
40	$ .10	$2.29/cwt.	$3.57	$4.86	1400
	.20	2.00	3.29	4.57	
	.30	1.71	3.00	4.29	
80	.10	2.80	4.60	6.40	1000
	.20	2.00	3.80	5.60	
	.30	1.20	3.00	4.80	
100	.10	3.25	5.50	7.75	800
	.20	2.00	4.25	6.50	
	.30	0.75	3.00	5.25	

*Adapted from J. A. Sims, and S. T. Slack, "Economics of Veal Production" Cornell University, Dept. of A. H., *Farm Flashes*, June 15, 1958.

Note in the above table that heavier calves, probably those of the Holstein, Ayrshire, and Brown Swiss breeds, can be more profitably raised for veal when veal prices are average or higher Because the calves are heavier at the start, less total milk is needed and more pounds of calf are increased in value The average veal price at major markets in 1961 was about $25 per cwt

Because whole milk is relatively high priced, much research has been directed toward dry diets or liquid milk replacers as feeds for raising veal calves Many satisfactory rations have been developed Most contain large quantities of milk by product ingredients (see Chapter 6)

Bull calves sold for veal or bob veal are usually not castrated They are slaughtered well before secondary sex characteristics develop Nearly all veal comes from dairy herds and breeds

In some cases it may be practical to raise bull calves for a longer feeding program, as bulls or as steers Profitability varies, of course, depending on veal and beef prices and on feed supplies and costs

As with feeding for veal, calves of the heavier breeds are more likely to be profitable when raised for prolonged feeding These large type cattle gain fast, utilize roughage effectively, and usually put on low cost gains (see Section 8 6, page 118) Such cattle do not produce top quality carcasses, according to present standards The carcasses are more angular and carry less marbling than carcasses from beef animals, but they do yield a high proportion of lean meat (see Section 23 11, page 335)

When beef prices are high and milk prices low, there is some tendency for dairy farmers to mate many of their cows, especially the poorer milkers, to beef bulls They probably do not anticipate saving heifers from such cows, and the crossbred calves produced would bring more as feeders and yield higher quality carcasses after feeding This is not necessarily recommended It decreases the opportunity for selecting herd replacements since fewer dairy heifers would be available Also, it is impossible to know *which* of the first calf heifers should be mated to a beef bull since they have not yet demonstrated their milk producing ability

28 9 Beef from Cull Dairy Cows and Heifers

Beef is a major by product of dairying It is estimated that about 40 per cent of the beef consumed in the United States comes from animals that are primarily of dairy breeding This figure includes the fed steers and bulls discussed in the previous section as well as heifers that do not enter the milking herd for various reasons, but a major portion is contributed by mature heifers and cows culled from milking herds About five million mature heifers and cows were culled from dairy herds in 1961[2]

[2] AMS USDA Crop Reporting Board *Milk Production* Feb 1962

Figure 28-7. Cattle of dairy breeding comprise a large portion of the slaughter cattle receipts at markets. They include steers, bulls, and culled heifers or cows. (Omaha Livestock Exchange)

Most of these were no doubt slaughtered and were a part of the 25.6 million mature cattle slaughtered that year (Figure 28-7).[8]

The marketing of cull cows and heifers for beef provides a major source of income to the dairyman. Refer to Section 22.8 for a discussion of supply and price trends for various classes and grades of slaughter cattle and Sections 23.6 and 23.7 for discussions of appraisal for slaughter.

Historically, most dairy cows have been culled and sold for slaughter in the fall for several reasons. Cows were bred so the peak of calving was in the spring. The cows had access to lush spring pasture, which helped production and held down production costs. After the grazing season, production dropped and more expensive, harvested feed was required. Also, cows that had been rebred and had not conceived could be noted by this time. This was considered a good time to cull cows for slaughter.

Prices of slaughter cattle, especially those of the lower grades, are usually lower in the fall. This is because of the large supply of grass cattle on the market.

In the spring the supply is usually lower and the price higher. Farmers and ranchers with plenty of grass compete with packers for lower quality cattle, even cull cows. Also, a lower proportion of the market receipts are of the lower grades. This also helps the price of slaughter cows.

[8] AMS, USDA Crop Reporting Board, *Commercial Livestock Slaughter and Meat Production*, January 1962.

In recent years there has been a trend toward spreading out calving in dairy herds throughout the year, so that production is more uniform This may decrease the tendency for culling most cows in the late summer and fall Such would have a significant effect in leveling out the supply of slaughter beef

Is it profitable to "dry up" cows and feed them extra grain before selling for slaughter? The answer to this question may not be the same in all cases If cows to be culled are fairly young and a good quality carcass can be produced, heavy grain feeding for one or two months may be very profitable The same may be true for cows that are in especially thin condition Most aged cows, however, are old enough that they usually cannot grade higher than utility The price of such cattle usually does not justify heavy grain feeding, especially for longer than a week or two

28.10 Contract Dairy Operations

Previous sections in this chapter discussed factors which influence the practicability and profitability of dairying It was pointed out that capital, labor, management ability, and/or some other item might be a limiting factor in making a dairy operation efficient and profitable Lack of capital may prevent purchase of equipment required by certain ordinances if market milk is to be sold It may also limit the size of a herd, so that equipment and facilities are not used efficiently and per unit production costs are high

It is also apparent that lack of a good, steady market for milk might prevent a dairy operation from being profitable

Certain dairy farmers, as well as processors and others, have attempted to counteract these limiting factors by several means Most such attempts have involved either *horizontal* or *vertical* integration in milk production and/or processing

In horizontal integration there are contract arrangements connecting several units that are at the *same level* in the "cow to consumer" movement of milk The merging of two or more creameries or milk plants, or the contracting to operate as one business unit, is horizontal integration The purpose is usually to increase efficiency and profit by handling more product, using equipment more efficiently, and improving distribution efficiency

Horizontal integration at the producer level might be in the form of a "cow pool," in which one party or an association provides all labor and facilities for handling, feeding, milking, and sheltering the cows Farmers, or other investors who own cows, may contract with the operator of the "pool" to manage, feed, and milk the cows, and sell the milk The operator of the pool deducts his charges from the sale price of the milk and returns the remainder to the owners of the cows

Several important principles should be emphasized (1) Two parties enter into a contract, neither has to sign until he is convinced the contract

is fair. (2) Each party should expect a return for the resources he provides. Contract arrangements vary, but in the previous example the pool operator should receive a return for feed, labor, investment in facilities and equipment, management ability, and any risk he might assume according to the contract. The owner of the cows should expect a return for *only* his investment in the cows and any risk pertaining to the cows. (3) A cow pool, as described here, is *not* an example of *vertical* integration. It represents simply a merger of several production units.

There are numerous advantages and disadvantages to contract milking arrangements. In general those interested in cow pools are:

1. Farmers who lack capital for expansion to an efficient unit.
2. Farmers who lack a good market for their milk.
3. Farmers who don't want to expand and can't justify expenditures that would be needed to modernize their present milking operations.
4. Farmers who lack the labor needed for dairying or want to semi-retire and be free from milking twice every day.
5. Investors (including farmers) who want to diversify their investments and may have confidence in the profitability of dairying.

Problems inherent in cow pool operations are similar to those associated with any large dairy unit. A large number of cows increases the possibility of disease and infection and makes the spread of such disease or infection easier and more costly.

Vertical integration would involve contractual arrangements between parties at two or more levels in the "cow to consumer" movement of milk. A producer may contract with a processor and distributor, the processor agreeing to provide a year-around market and the producer agreeing to give the processor a constant supply. Feed companies, too, are interested in contractual arrangements with dairymen.

Situations adapted to vertical integration, and the reasons companies are interested in vertical integration, are the same for dairying as for contract feeding of livestock (see Section 10.8).

29

SELECTION FOR MILK PRODUCTION

It is worthwhile for the reader to review at this point the four rules for effective improvement of livestock by selection, given in Section 14.6. Rule Number 3 was "Observe or measure accurately the traits carried by a prospective breeding animal." This chapter is devoted to the appraisal of milk producing capacity and other economically important traits of dairy heifers and cows, as well as appraisal of the genetic merit of bulls that might transmit these traits to their offspring.

Dairy heifers are selected (1) for their own life time production and (2) as a breeding animal to produce high quality daughters and sons. The incentive for accurate selection is high. Bulls are selected solely as breeding animals. Selection incentive is even higher for them than for heifers, however, because of the larger number of offspring they might sire.

Most of the material in the introduction and Part A of Chapter 16, Appraisal of Breeding Stock, also applies here. The reader should review those pages before proceeding with this chapter.

The first sections of this chapter are devoted to appraisal of heifers and cows. Accurate sire selection, discussed in Section 29.11, is highly dependent on accurate appraisal of their daughters and other relatives—cows and heifers in milking herds.

29.1 Selection Within a Herd

Efficient and maximum long time production is the goal in selecting heifers and cows for a dairy herd. Most rapid progress toward this goal can apparently be made by (1) putting essentially all heifers into the milking herd, culling from the lower end of the producing cows,[1] and (2) exerting nearly all selection effort toward production and ignoring conformation, except for serious defects which would obviously shorten productive lifetime of the animal being appraised.[2] This item is discussed further in later sections of the chapter.

[1] M. H. Fohrman, "Breeding Experiments with Holstein Friesian Cattle," *USDA Tech Bull 1220*, 1960.

[2] N. D. Bayley *et al*, "Dairy Type: Its Importance in Breeding and Management," *USDA Tech Bull 1240*, 1961. This bulletin contains numerous illustrations and many citations to original research on this topic.

Selecting or discarding heifers solely on the basis of their dam's production permits many selection mistakes. A heifer receives only 50 per cent of her genes from her dam; the remainder are from the sire. Also, heritability of milk production is only about 30 per cent. The practice of culling low producing cows on the basis of their *own* production permits more accurate selection (see also Section 29.8)

Also, when excellent bulls are used (more generally possible with artificial insemination), many heifers will be higher in producing ability than their dams. In fact, a heifer may *exceed* her dam's production, even though she be younger. For maximum herd production, in such a case, the heifer should be saved and her dam culled.

There are economic considerations, however. A dairyman wants to make most rapid progress in raising herd productivity only if it maximizes profit. The feasibility of putting essentially all heifers in the herd and culling from the low end of producing cows depends, in part, on the cost of raising all heifers to maturity and the salvage of cows culled after one or more lactations. Also, *on the average,* heifers produce less milk during a lactation than do mature cows.

29.2 Significant Records to Keep

As with other animals, the best record systems are the simplest. They will more likely be maintained and used. The common and essential component of any worthwhile record system is positive, readable identification of every animal (Section 16.5).

The most significant records pertain to the cow—calving and breeding dates, milk and butterfat produced, etc. The recorded performance of a cow can then also be an indicator of the performing ability of her daughters, her sire, and other animals related to the cow.

What records are worthwhile to have for continued evaluation of a cow in the herd or for appraisal of daughters and other relatives? Birth date, name or number of sire and dam, breeding dates, and calving dates should all be recorded. These dates help in routine management of the cow herd and, if converted to disclose the age of the animal at each important event, serve as important appraisal information. They show how readily the heifer conceived when bred, length of pregnancy, uniformity and length of calving interval, and other economically important characteristics (see also Section 16.6, page 227).

It is usually worthwhile to record vaccination dates and growth rate as measured by body weight at a standard age. Many dairymen record such subjective information as temperament, speed with which milk is "let down," speed of milking, ease of milking, etc. This is of less significance in a small herd managed by a single man who knows all cows well, but essential to intelligent selection in a large herd.

Recognize that the performance of a cow is not a perfect indicator of

the performing ability of her daughter or other relative. A heifer receives only 50 per cent of her genes from the dam, and more distant relatives probably have a smaller proportion of identical genes. Also, environment influences certain traits considerably, perhaps masking the true genotype of the animal.

29.3 Milk Production Records

Milk is the product of dairying. Though reproductive efficiency and other traits are important in a dairy herd, most selection effort should be exerted on production. Exerting some selection for conformation in dairy cattle may, in fact, be a deterrent to continued progress in production. Less progress in production can be attained if selection effort is exerted on both production and conformation.[3]

Production information recorded always includes volume or pounds of milk produced, usually percentage and pounds of butterfat, and sometimes the percentage and amount of solids-not-fat. It may also include percentage of protein or other milk constituents.

Since the dairyman is interested in production records as a measure of genetic merit (productive potential or breeding value), efforts are usually made to standardize records for environmental influences which exist. A lactation record, for example, would specify which lactation (first, second, third, etc.), age at calving, days milked, number of milkings per day, length of time a calf was carried during lactation, etc. The extent to which each of these environmental factors influences production is fairly well known, so records can be adjusted to a standard set of circumstances for comparison purposes. This is essential for records to be really useful.

A standard lactation length of 305 days is used for many comparisons. Table 29-1 shows the factors commonly used to convert, by multiplication, lactation records to the 305-day basis. Adjustments for other variables can be made similarly.

Table 29-1. Factors for Converting Production to a 305-Day Basis

Days in lactation	Factor	Days in lactation	Factor	Days in lactation	Factor
240 or less	1.15	320	0.96	345	0.91
241 to 270	1.06	325	0.95	350	0.90
271 to 309	1.00	330	0.94	355	0.89
310	0.99	335	0.93	360	0.88
315	0.98	340	0.92	365	0.87

[3] N. D. Bayley *et al.*, "Dairy Type: Its Importance in Breeding and Management," *USDA Tech. Bull. 1240*, 1961.

If a cow is milked three times per day rather than two, her record is usually multiplied by 0 83 if she is under three years of age, 0 85 if under four, and 0 87 if four years of age or over Example adjustment factors for age of cow (at beginning of lactation) are given in Table 29-2 Note that the ages of six to eight years are generally considered standard, and production of older or younger cows is adjusted upward

Table 29-2. Factors for Converting Production to a Standard Age

Age, years	Ayrshire	Brown Swiss	Guernsey	Holstein	Jersey	Milking Shorthorn
2 0	1 30	1 45	1 24	1 31	1 27	1 42
2 5	1 24	1 35	1 18	1 24	1 21	1 30
3 0	1 18	1 23	1 12	1 18	1 15	1 24
3 5	1 13	1 16	1 08	1 12	1 09	1 18
4 0	1 10	1 10	1 06	1 08	1 06	1 13
4 5	1 06	1 07	1 04	1 04	1 03	1 10
5 0	1 03	1 04	1 02	1 02	1 02	1 07
5 5	1 02	1 02	1 01	1 02	1 01	1 04
6 0	1 00	1 00	1 00	1 00	1 00	1 01
7 0	1 00	1 00	1 00	1 00	1 00	1 00
8 0	1 00	1 00	1 01	1 00	1 01	1 01
10 0	1 03	1 02	1 04	1 04	1 04	1 04
12 0	1 06	1 06	1 08	1 09	1 08	1 08
14 0	1 09	1 10	1 12	1 15	1 12	1 12

Figure 29-1 illustrates calculations made to adjust production of a three-year-old Holstein cow, milked three times per day for 315 days in her second lactation The adjusted record is the estimate of what that cow would produce if she were six or seven years of age (mature), and milked two times per day for a 305-day lactation

Figure 29-1 Adjustments made in the lactation record of a young Holstein cow so her record can be compared, on a standard basis with others

A three year old Holstein cow milked three times per day for 315 days produced 10 000 lbs of milk

Adjustments

A Length of lactation

10000 lbs x 98 9800 lbs

B Times milked per day -

9800 lbs x 85 = 8330 lbs

C Age

8330 lbs x 1 18 = 9829 lbs

The adjusted record 9829 lbs is the production expected if the cow had been mature and milked twice a day for 305 day lactation (This adjusted record is called a mature equivalent record)

Other environmental factors that exert temporary or permanent influences on production should be made a part of the record, so that the record might be more intelligently evaluated, especially after several years elapse and the dairyman's memory fades Sickness, udder injury or infection, or loss of a quarter should be noted Extremely hot weather that cuts production, or a short and poor quality feed supply for a time, would influence the whole herd but might still be noted Different cows will be at different stages of the lactation curve, production may be cut only slightly among some cows and severely among others (see Section 30 3, page 436) Also certain cows in the herd may be dry at the time of this environmental influence so their production records would not be affected

Season of the cow's lactation, level of management, length of dry period preceding the lactation, and many additional factors obviously might influence production

Personal knowledge of existing environmental conditions, and of the reactions of individual cows to these conditions, permits improved selection accuracy The dairyman can do a fairer job of interpreting a set of records and deciding how much influence they should have on his selection decisions

29.4 Milk Composition and Appearance

The percentages of fat and of solids not fat were mentioned in the previous section as components of certain record systems Just as there is much variation in volume of milk produced among cows, there is also considerable variation in composition of the milk (see Table 28-1, page 405) This may influence the value of milk produced

There is also variation in color, flavor, and aroma of milk These characteristics have not been deeply studied from a genetic standpoint It is probably safe to assume, however, that some of the variation which exists is caused or permitted by variations in genotype Therefore, such information might be recorded and used in selection decisions

29 5 Organized Record Keeping Programs

The United States Department of Agriculture, state extension services, and breed associations have done much to develop and encourage the use of record keeping programs for dairy cattle In the total livestock industry these organized programs have been the forerunner of "production testing" They have served as a demonstration to swine, poultry, beef, and sheep raisers that records of performance are worthwhile, practical, and usable in attaining genetic improvement by selection

Why were the dairy record programs the first to develop? Dairymen may have been more receptive to such programs simply because they have long been more conscious of production and the differences in pro-

duction which exist among cows. They notice these differences twice every day. Swine and poultry raisers and some beef cattle men have recently participated in organized record programs, but in most cases *only* after it was clearly demonstrated that large differences in productivity exist in these species, too, even within herds.

Though dairy record programs are of long standing, only about 15 per cent of the dairy cows in the United States are in one of the organized programs.[4] These programs include Dairy Herd Improvement Associations, the Owner-Sampler program, and Weigh-A-Day-A-Month program, all available to any dairyman, as well as several programs used in purebred herds and officially recognized by breed associations.

The DHIA program is most popular. On January 1, 1961, about 11 per cent of the milk cows in the United States, in about 42,500 herds, were in the program. Average production of such cows during 1960 was 11,045 pounds of milk and 428 pounds butterfat (3.9 per cent butterfat).

Though this program is sponsored by USDA and state extension services, individual associations are formed in producing areas. These usually include one or two counties, depending on density of cows. An employed supervisor visits each farm one day each month to weigh and sample the milk from each cow (Figure 29-2). This includes both a morning and evening milking. The percentage of fat in the milk is determined and recorded for each cow. He records the amount of concentrate fed each cow, the amount and quality of roughage fed, and other information on individual cows—calving dates, dates cows are dried up, etc.

[4] ARS, USDA, *Dairy Herd Improvement Letter*, Feb. 1961, and Dec. 1961.

Figure 29-2. The DHIA supervisor visits each herd once a month to weigh and sample milk of each cow and record other data. (Iowa State University)

The supervisor may then compute monthly and cumulative production information, estimated feed consumed per unit of production, and other desired information and enter these data in the dairyman's herd-record book The present trend, however, is toward central machine processing of the data collected by the association supervisor Electronic computers can provide more information on DHIA herds, in less time, and with complete accuracy Some expense is involved, of course, but the association supervisor has time to check more cows each day because he no longer spends time computing summaries He merely mails recorded data to the central data processing point The electronic computers summarize the desired information and printed herd reports are mailed to the herd owner, usually within 7 days after the herd is tested Figure 29-3 is an example of a monthly report The following page explains the information provided on this sample report

Because of the cost of complex electronic computers, they must be fully used for handling dairy records or for other work Cornell University, North Carolina State College, Washington State University, Utah State University, Ohio State University, and Iowa State University process records for their own and certain surrounding states

In addition to production and estimated efficiency summaries for each cow and the herd, the summarized reports give considerable management information, such as milk produced per worker, return above feed cost per worker, age at last calving, and reminders for breeding and drying up cows

In the Owner-Sampler program the dairyman records milk weights and takes milk samples one day each month, in sample bottles left by the DHIA supervisor The supervisor collects the samples the next day, tests for butterfat, and records data similar to that recorded in the DHIA program Here, too, summaries may be computed by the supervisor or at a computing center This program is less costly since the supervisor need not be present during milking and can cover more herds per day

In the WADAM (Weigh A Day-A-Month) plan the dairyman simply weighs each cow's milk morning and evening on the fifteenth of each month He records the weights on special forms and mails them to a central office or computing center The records are then summarized and returned

Some might question the value of such a program as WADAM Since the dairyman weighs his own milk, why can't he summarize his own records? He certainly could, but unless he belongs to an organized program, he might feel less obligation to do it He might neglect to take regular weights or might not take the time to summarize the records and compare cows Such a program also allows a dairyman to compare the average production in his herd with averages of other herds This may provide some stimulus for trying to achieve improvement

Dairy breed associations recognize records gathered under certain organized programs as bases for certifying the breeding value of purebred bulls, as well as for validating the producing ability of cows.

An increasingly popular program used by owners of purebred herds is DHIR (Dairy Herd Improvement Registry). This is identical to DHIA, except that central processing of records is required and check testing is stipulated for animals or herds whose records are surprisingly high. Completed lactation records are sent directly to the breed associations.

The development of central processing of DHIA records made this program entirely practical for breed association use. Since most purebred herds are located in areas where there are numerous dairies and where Dairy Herd Improvement Associations exist, it is efficient to use the same supervisors and procedures for recording production in the purebred herds.

While the DHIR program is identical for all breeds, some special record programs sponsored by dairy breed organizations differ among the breeds. The various programs fit well into two groups, Herd Improvement Registry (HIR), and Advanced Registry (AR). Other names might be used by certain breeds.

Both HIR and AR are supervised by state agricultural colleges according to breed rules. In most HIR programs, the DHIA supervisor gathers the same monthly data on the entire herd as in the regular DHIA program. Monthly records are sent through the State Superintendent of Official Testing (usually a dairyman at the agricultural college) to breed association offices for further calculations and comparisons. Since the sire of each registered cow is known, the daughter's production records may be recorded as evidence of her sire's genetic value.

The Advanced Registry program is used by a limited number of purebred herd owners. Selected cows may be tested rather than the entire herd. Daily milk weights are usually taken and butterfat is checked monthly. Such programs are usually used only to publicize the production of especially high producing, valued cows.

29.6 Use of Records

Production records on cows in the milking herd are used as an indicator of the producing ability of daughters that might be herd replacements. They are used also to determine which cows, if any, should be culled. The third major use of production records on cows is the evaluation of the genetic merit of bulls—sires, brothers, sons, or other relatives of the cows (Section 29.11).

An additional use of production records is not associated with the function of this particular chapter, though it is highly important. Production records provide much help for *managing* a dairy herd. Refer to the vast amount of information contained on the sample DHIA monthy summary report in Figure 29-3 and to the explanations accompanying it.

Herd No. A	Av. body wt	Number cows	Days in milk	Days milked	Milk	% test	Fat	Concentrate fed $	% NE	Succulents fed $	% NE	Dry roughage fed $	% NE	Pasture	% NE	Silage	Days	Value of product $	Unit	Feed cost $	Income over feed cost $	Feed cost per cwt milk $	Number of workers	1000 lbs of milk per worker	$100 return above feed cost per worker
Day average		16	83		34.4	3.8	1.3	9	36	40	26	18	38				2.4	1.39	.21	.48	.85				
Herd totals					1609		616	524		970		662		268				569	111	257	312				
Year	13	15.4	87		10450	3.9	400	34	39	63	18	43	27	174	21	107	2.3	370	72	139	231	1.33	.5	321	62

Breed	Registration or tattoo number of cow	Status	Mo.	Da.	Daily milk	% test	Concentrate lbs	Concentrate %	Barn name	Cow index number	Current test period: Days in milk	Milk lbs	Fat lbs	Age at calving (mos.)	Body cwt	Number days: Dry	Calving to calving		No. of days	Lactation to date: Milk pounds	% test	Fat pounds	Value of product $	Income over feed cost $	Long.
1	3025786	1			290	4.5	8	5	9	9	31	900	41	177	12	61	167		243	10060	4.3	431	443	311	
1	3742388	1			537	3.8	8	13	26	26	31	1660	63	94	15	52	111		199	10600	3.6	381	390	286	
1	3742086	4	12	21	495	3.7	10	13	DUCHES	28	31	1530	57	74	13	31	46		106	6750	3.6	242	247	189	
1	4166888	0							AMY	42				73	14	47	[illegible]		305	10800	4.0	436			#
		1			279	4.2	8	5			31	660	36	73	[illegible]	[illegible]	270		327	11410	4.0	461	461	306	
1	4136859	0							BELLE	44				[illegible]	[illegible]	[illegible]	198		274	10530	4.3	454			#
		4	1	4			2	4						61	13	31	229		274	10930	4.3	454	462	307	20
1	4136861	1			414	3.9	8	7	SUSAN	45	31	[illegible]	[illegible]	59	12	49			85*	4190	4.2	177	178	135	
1	42MAG5637	1			293	3.3	13	6	OPAL	[illegible]	[illegible]	[illegible]	30	49	14	62	226P		303	10010	4.0	404	413	267	1
1	42OAE1992	3					5	4	SPOT	[illegible]				31	14	113	210		478	17930	4.1	707	702	455	
1	42XA81634	0							PHROS	49				40	14	53	283		359	15200	3.6	546	552	348	□
		2	12	31	626	4.1	12	16			33	2070	85	53	19	53			33	2070	4.1	85	74	061	
1	4467794	1			378	3.4	8	7	MARY	51	31	1170	40	39	14	55	86		146	6780	3.9	264	270	196	5
1	4635319	1			468	3.4	8	11	B.ETHL	52	31	1450	49	26	12				97*	4340	3.5	153	157	114	
1	4635320	1			525	3.6	12	15	GRACE	53	31	1630	59	25	10				90*	4500	3.8	169	171	131	
1	4513970	1			466	3.5	8	12	SALLY	54	31	1440	50	31	11				69*	2650	3.8	100	104	078	7
1	4727343	4	1	20	508	3.0	10	11	MYRT	56	31	1570	47	26	11		16		63	3530	3.5	122	121	095	
1	4443643	7	12	25			5	7	HAZEL	57					14									-019	
1	4169797	7	1	10	225	3.9	13	6	SMITH	58	26	590	23		13				26	590	3.9	23	22	010	
1	42XA83971	2	1	18			10	4	EMBLEM	59				25	12									-008	9

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anation of Sample Herd Sheet

onth herd total and 12 month herd ry provides appropriate data for erd that completed a year of DHIA ws between July 1 1958 and June 30, l serve as a useful comparison for d compilations

1 26 Normal cows in milk no change of status since the previous month
d 56 Now a breeding date is shown
w completing a 305 day record while still in milk (# in Condition Affecting Record (C A R) column)
ow terminating a lactation record of less than 305 days by being sold (# and ☐ in C A R column)
52 53 and 54 (* in milk) Breeding reminder
* in days carried calf) Drying off reminder
hous estimated record this month (1 in C A R column)
ow dry both last month and this month
ow dry last month calved again old record terminated new record started (☐) in C A R column
ow abnormal mastitis (5 in C A R column)
ame on test day, foot rot (7 in C A R column)
ow purchased while dry (negative income over feed cost)
ow purchased while in milk calving date or previous production not known
emporary nurse cow too soon to test (9 in C A R column)
48 49 59 Eartags for grade cows
53 54 56 59 First calf heifers no days previous dry period
9, 3* Old barn name abbreviated to conform to 6 space central processing limit
n lines with no cow identification numbers barn names or index numbers provide additional data for the cow on the preceding line
[illegible]

The dairyman is able not only to compare cows on monthly production, but also to compare cumulative figures He is usually given averages for other herds to compare with his herd averages

A feeding index shows how the herd's feed consumption compares to that which should be needed for maintenance and the reported milk production The dairyman can therefore compare the efficiency of his herd with a standard DHIA monthly summaries also show the pounds of concentrate that should be fed each cow per day, according to her present weight and production Other management helps are also given

Production records are of increasing value in merchandising heifers, cows, and bulls, whether they be surplus stock or part of a herd dispersal Not all records are good records, but a prospective buyer appreciates the availability of records to supplement his visual appraisal of dairy stock

29.7 Selection Standards for Heifers

Though putting essentially all heifers into the milking herd and culling from the bottom end of producing cows may permit most rapid genetic progress, the cost of raising heifers and salvage value of mature cows may dictate some selection among heifers

It was mentioned in Chapter 28 that only about 35 heifers could be raised per year in a 100-cow herd and that about 20 of these would be needed for herd replacements just to maintain herd size These figures are merely approximations, but do indicate there is a limit to the severity of selection where it is to be practiced on heifers If standards for selection are set too high, not enough heifers can be saved

If all heifers are healthy and without conformation defects, selection might be solely on producing ability, as measured on dams If the heifers under consideration were sired by different bulls, the genetic merit of each bull (as summarized from production of daughters or close ancestors) might also be used to appraise the producing ability of individual heifers

Dairy heifers are born throughout the year and some reach breeding age each month so they can't be compared as a "crop" of heifers, as is possible with ewes, beef heifers, or gilts Instead, the dairyman must usually set a minimum standard for each trait—one that is reasonable and practical in his herd and breed—and save only those heifers that meet the standard in each trait

The dairyman might also develop some type of "index" or "total merit score" to appraise heifers (see Section 16 11, page 234) The index would give weight to each trait according to the economic importance of the trait, the heritability of the trait, and whether the trait was appraised on the animal considered or on a relative In most commercial herds production would dominate any index so would almost control the selection decision In certain purebred herds where type and conformation are considered important, this would not necessarily be true

but there are other considerations Cows near to calving generally sell for more The seller has borne the major cost of pregnancy and the buyer will soon have a new calf, plus a cow at the peak of her lactation curve Price of beef—salvage value of the cow—also has an influence

29.10 Visual Appraisal

Because some selection in dairy cattle is done before the heifers are in production and because a relatively small percentage of the dairy herds are on record programs, some appraisal of animals for the milking herd must be done visually

In many cases, visual appraisal is used only as a *supplemental* tool in selection Dairymen are generally more acquainted with production traits (even when production records are not maintained) of individual animals in the herd than is the owner of a beef or swine herd or of a sheep flock Also, in over 50 per cent of the cases, the dam is still in the milking herd (being milked twice daily) and the owner needs to rely less on *memory* of the dam s production traits

The effectiveness of visual selection within a herd depends on the degree of relationship between visible traits and production Effectiveness also depends, of course, on the accuracy with which people can see and appraise physical characteristics In other words, one who appraises animals visually must have a trained and experienced eye He must be able to see what is there, remember what he sees, and discriminate among potential herd replacements when the selection decision is to be made

Correlations between conformation traits and production are rather low (Table 29-4)

Table 29-4 Approximate Correlations Between Certain Conformation Traits and Milk Production*

Traits[1]	Correlation coefficient
"Dairy type" rating	0 16
General appearance	0 10
Dairy character	0 24
Body capacity	0 08
Mammary system	0 12
Feet and legs	0 04

*Adapted from N D Bayley *et al* *USDA Tech Bull 12*40 1961

[1]Type ratings are applied by experienced cattle appraisers according to conformation criteria established by breed organizations Standards used for other traits are usually those found on the Dairy Cow Unified Score Card prepared by The Purebred Dairy Cattle Association and approved by The American Dairy Science Association They are briefly described in later paragraphs

Note that the individual trait "dairy character" is more highly associated with milk production than is "dairy type" rating, an over-all conformation appraisal. Dairy character, then, seems to be the best visible indicator of the production of a cow.

The fact that repeatability of milk production, given in Table 29-3, is much higher than the correlations in Table 29-4, is evidence that selection on the basis of one lactation record is *more accurate* and permits *more rapid genetic progress* than selection on the basis of any or all conformation traits. This has been demonstrated repeatedly.

Items normally considered in visual appraisal are briefly discussed in the following paragraphs.

Mature Size. Within a breed, larger type heifers (stretchy, large-framed) are usually preferred. Larger heifers usually eat more feed and produce more milk. Essentially no more labor is needed to milk a high producer than a low producer so the proportionate labor costs would be less. Larger heifers can usually be bred at an earlier age, usually calve easier, and can make better utilization of forage.

Larger heifers are more rugged, better able to withstand stress and disease. They can wade through muddy lots, for example, and their udder is higher off the ground so it stays cleaner and is less likely to be injured.

Calves from large type heifers and cows are larger, too, so they are more likely to get off to a good start, especially if raised in poor environmental circumstances.

There is another advantage of large size in dairy cattle. Bull calves raised for veal or castrated and sold for steer feeding are more profitable. See Table 28-2, page 407, concerning veal. Cattle feeders who want to market roughage through low quality cattle prefer larger type cattle. They can utilize more roughage that is lower quality and a larger proportion of their ration can be roughage. They usually gain faster and therefore more efficiently.

Recognize that the above discussion pertains to relative size *within* breeds. Some of the points mentioned apply to comparisons among breeds also. But comparisons among breeds should also include many other important considerations, such as milk composition (Table 28-1), consumer demand, personal preference, and others.

Body Capacity. Body capacity is obviously related to mature size, but there is also variation in body capacity *among cows or heifers of the same size*. Body capacity refers to the room in the thoracic cavity for the heart and lungs to operate, as well as in the abdominal cavity for the digestive system to handle large volumes of feed and water.

A large body capacity is desired. A heifer should be deep in the chest as well as at the rear rib. She should have a lot of "spring of rib"—the ribs should spread out wide from the backbone. The third dimension is length. A longer thoracic or abdominal cavity, of course, has more room.

Bear in mind that this discussion concerns body capacity *in relation to*

total size or weight A large heifer that is shallow bodied and narrow through the ribs cannot handle large enough volumes of feed

Differences in body capacity in relation to body weight may explain much of the variation in efficiency of milk production noted among cows of the same size (Section 28 1)

Dairy Character. This term, dairy character, may seem rather vague To a dairyman the term means refinement—freedom from fleshiness or fatness—noticed especially in the neck, withers, and thighs If an animal has much dairy character, the neck is long and lean, and blends smoothly into the shoulders The withers are sharp, the ribs wide apart and easily counted, and the thighs flat or concave

All this is taken as evidence that the cow, when mature, has a genetic tendency to put the nutrients she consumes into milk during lactation, rather than to tissue growth—lean muscle and body fat

Certainly a dairy heifer must grow in order to reach mature size But if she is well managed, using maximum proportions of roughage in her ration, she should not show a tendency to fatten Nutrients should be used for growth in *size*, with emphasis on *skeletal growth* (see also Figure 7-9)

Dairy character is usually more apparent in mature cows, but can be appraised with some accuracy in young heifers Though it is more highly correlated with production than other conformation traits or any "total conformation score," its use for appraising immature heifers is still limited[5]

Mammary System. The mammary system includes the udder and the teats The udder should have the capacity for large volumes of milk, be firmly attached to the body, and the teats should be shaped and spaced so the cow can be milked easily

Udder capacity can be appraised most accurately just before milking and when the cow is at the peak of lactation Volume of milk secreted is, in part, influenced by udder pressure If the udder has a small volume, less milk can be produced because pressure builds up to slow or stop secretion In a large capacity udder more milk would be produced before the pressure reached a high level

It is worthwhile to check the udder closely *after* milking, too If the udder contains only secretory tissue, plus cisterns for storage of milk secreted between milkings, the udder after milking will appear completely collapsed and very small If the udder contains considerable depositions of permanent fatty and other tissue (often called a meaty udder), the udder will not appear collapsed after milking Instead it will retain a fairly definite, full shape It is apparent that an udder with considerable nonsecretory tissue has less volume for storage of secreted milk than does an udder of the same size which contains only secretory tissue

[5] N D Bayley *et al* "Dairy Type Its Importance in Breeding and Management." *USDA Tech Bull 1240* 1961

In immature heifers the presence of only secretory tissue is difficult to appraise. Most dairymen check the udder of a young heifer by feel. The udder should be very soft and pliable, rather than firm and meaty.

The udder should be firmly and securely attached, especially in a large heifer that is expected to produce large volumes of milk. The front and rear attachments are most noticeable; these should be long and smooth, without a sharp break between the body and the udder. The middle ligament, which runs longitudinally between the two sides of the udder, is more important for support, however.

Strength of udder attachments and supports is also difficult to appraise among young heifers. It is most easily appraised on aged cows, which have been in the herd for many lactations. Those with strong udder attachments are obvious. Those with weak attachments are equally obvious. The udder is pendulous. Teats may be close to the ground. Sharp breaks are evident between the body and udder at the front and rear. If the middle ligament is weak the center of the udder is low and the teats point out to the side.

Strength of udder attachments may be inherited to a degree. If so, since the trait is appraised easily on mature cows, heifers might be more accurately appraised by checking the dam, perhaps still in the herd, than by checking the heifer directly.

The teats should be of the size that will be conducive to machine milking. Some teats are too large. The teats should be of medium length and cylindrical, shaped more like a short test tube than a cone. This allows for easier machine milking because it permits more uniform pressure on the teat in the milking process and less teat injury.

The teats should be far enough apart to allow machine use. They should point straight down, perpendicular to the ground.

Ease and speed of milking is influenced, to a degree, by teat shape and placement, as well as by relative lack of nonsecretory tissue in the udder. A greater influence, however, is probably the size of the streak canal through which the milk leaves the teat and the flexibility of the tissue surrounding this canal. This is difficult to detect in immature heifers. Again, the appraisal may be more valuable if made on the dams or sisters of the heifers being considered.

Presence of prominent and tortuous "veins" along the belly in front of the udder, as well as on the sides of the udder, was formerly thought to be evidence of high milk producing capacity. In fact these veins were often called "milk veins" even though they carry only circulatory fluids (milk is formed in the udder). There is no available evidence that prominence or tortuous nature of these veins is significantly correlated with milk production.

Feet and Legs. Feet and legs should be structured for maximum strength and support. A two-year-old heifer selected to go into a dairy herd may carry eight or more calves during her lifetime, stand on concrete from

2,400 to 60,000 hours (depending on method of management), and/or walk hundreds of miles grazing

The four legs should be set out on the corners so each carries a proportionate share of the weight They should be straight so there is less stress on the joints, the long bones, and the muscles that support them. The pasterns should have enough slope that they cushion each step. Legs should show evidence of large, strong bones, especially on large type heifers

Good legs for *grazing* are of less concern than formerly, as more dairymen shift to strip grazing, the cows walk less each day Some producers feed all forage to their milking herd in confinement This does not reduce the need for straight and strong legs, however Most cows kept in confinement spend much of their time on concrete, which provides little cushion in walking or standing

29.11 Sire Selection

Since artificial insemination is being used in an increasing percentage of herds (over one third of the herds in the U S in 1961), many dairymen are not concerned with bull selection, except as they might choose semen from certain bulls Certainly much more genetic progress can be made, however, in sire selection than in selection among females *Selection* can be more *severe* because relatively few bulls are needed, and *appraisal* can be more *accurate,* utilizing records on many daughters and other relatives Also, once "the best" sires are chosen, their merits can be spread rapidly and widely to many calves

The expectation of continued increase in use of artificial insemination suggests devoting this section primarily to choosing bulls for artificial insemination organizations or "studs"

Artificial insemination has provided both the incentive and means for extremely accurate sire selection Some bulls used in artificial inseminations sire over 20,000 calves per year A few have sired as many as 500,000 calves in their lifetime With this number of progeny, the value of "the best" sire becomes almost phenomenal It becomes justifiable to spend considerable money and effort to insure that only the best are chosen for use

Many artificial breeding organizations select bulls through a "young sire" testing program This program operates on the accepted premise that performance of *daughters,* located in many herds and compared with records of other cows in those herds, is the only satisfactory measure of a bull's genetic merit.

Young bulls—three to five for each vacancy anticipated in the stud—are chosen for the testing program on the basis of records available on their dams, sires, or other relatives As soon as a young bull in the

program is sexually mature (about 18 months), semen is collected and distributed to technicians for random use. The goal is to obtain production records on 30 to 50 daughters. Since only about 11 per cent of cows are on DHIA testing programs, and since some cows bred will not conceive or calve and only half the calves will be heifers, semen for inseminating 1000 to 2000 cows from each young bull may be distributed.

The cost of such a program is evident when one realizes that all young bulls in the testing program must be boarded *four to five years,* from sexual maturity until the results of the test are known. It has been demonstrated, however, that the accuracy achieved by this method of sire appraisal justifies the expense and time involved. Sires chosen by this method are usually termed A. I. (artificial insemination) or A. B. (artificial breeding) proven.

Selection of bulls for natural service in dairy herds is usually based on production of the dam, sisters, and other relatives. Bulls with producing daughters can be more accurately appraised. The daughter's production can be compared with that of its dam or its contemporaries—other cows in the herd that calved in the same season and perhaps are the same age.

29.12 Breed Color Standards

Color, as such, has no known significance as an influence on, or in relationship to, milk producing characteristics. Certainly the breeds differ in typical color patterns, just as they differ in production, but evidence indicates the two factors are inherited independently. In other words, the presence of a certain color gives no assurance of high production, high butterfat, or longevity of production.

Selection within the breeds has apparently been rigid and effective for specific color patterns. At the same time, selection has caused members of each breed to be fairly consistent in many production traits. But selection for the two factors has been independent; one does not cause the other, as far as is known.

Shades of color and patterns of spotting or color markings designated by breed associations as being requisites for registration are not discussed within this text. Such color standards allow the breed to have an identifiable "trademark" and may certainly influence price of purebred animals, but are of no concern in selecting solely for milk production.

30

MILK SECRETION

Milk is secreted in all species of farm livestock, so the information and discussion in this chapter pertain to all these species, not just to dairy cattle Dairy cattle, however, have been developed *primarily* for milk production Since selection for this trait over hundreds of years has been effective, present dairy cattle are extremely efficient as milk producers compared to beef cattle or other species (Table 30-1)

Table 30 1 Approximate Milk Producing Ability of Farm Livestock

	Av pounds per day during lactation	Percentage of body weight per day
Dairy cow	32	2 5
Beef cow	10	1 0
Sow	2	0 7
Ewe	2	1 6

Beef cows, sows, and ewes are expected to produce only enough milk to nurse the young until they are ready to eat sufficient grass or dry feed In fact, ranchers sometimes complain about cows which give more milk than the calves can take, or fail to dry up after the calves are weaned If production is excessive, such cows may need to be milked out regularly

The above paragraph should not disinterest the beef, swine, or sheep man from studying milk secretion, however There are some animals in these species which produce *too little* milk As we learn to increase prolificness in livestock, this becomes a more serious problem A few fail to "let down" milk after parturition so the young can nurse

Influences of feeding and management can affect the amount, composition, and desirability of milk produced by these species for their young just as they may influence amount, composition, and desirability of milk produced by dairy cows for human consumption Further, those who may

not be dairymen still *drink* milk. To a consumer, the topic of milk secretion may hold considerable interest.

Though principles discussed here do apply to all species, most examples and illustrations pertain to milk secretion in dairy cattle.[1]

30.1 Anatomy of the Udder

Figure 30-1 presents a top cutaway view of the udder of a dairy cow. Note that the right and left sides are separated by a thick layer of connective tissue. This middle suspensory ligament carries much of the weight of the udder. It was mentioned in Chapter 29 as being important in keeping the udder snugly attached and the floor of the udder level. The two quarters on each side of the udder have separate duct systems and are supplied by separate networks of arteries. Each quarter, therefore, operates almost as an independent unit.

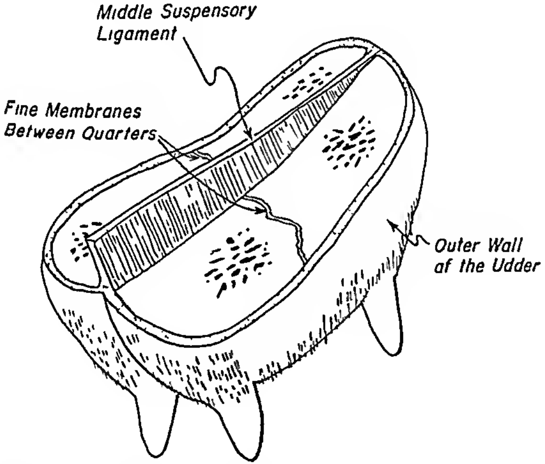


Figure 30-1. A top cutaway view of a cow's udder. Note the thick center membrane and the outer walls which provide most support.

[1] More complete information on milk secretion is available from several sources, including *Physiology of Lactation*, 5th edition, by Vearl R. Smith, Iowa State University Press, Ames, Iowa, 1959; *The Mammary Gland*, by Charles W. Turner, Lucas Brothers, Columbia, Missouri, 1952; and *Dairy Science* by W. E. Petersen, J. B. Lippincott Co., New York, 1950.

All quarters of the udder are not necessarily the same size The rear quarters are usually slightly larger Together, they produce about 60 per cent of the milk while the forequarters produce about 40 per cent. If one quarter of an udder is lost, by injury or infection, the remaining quarters usually expand slightly and each produces more milk The total production in such cases, though usually is not equal to the production before loss of the quarter

The functional tissue in the udder—that which produces milk—is called secretory tissue It consists of many small cell groups, called *alveoli*, in each quarter An alveolus is lined with many cells, each is capable of secreting milk The physiology of this secretion process is discussed in the next section, but it is important to note here that, for secretion to occur, each cell must be supplied with nutrients and milk precursors via the body circulatory systems If *many* small groups of secretory cells exist in each quarter, it is apparent that the blood and lymphatic systems must include a *profuse network of capillaries* to reach every cell

The many groups of alveoli in each quarter connect, through a series of ducts, with the milk cistern near the base of the quarter (Figure 30-2)

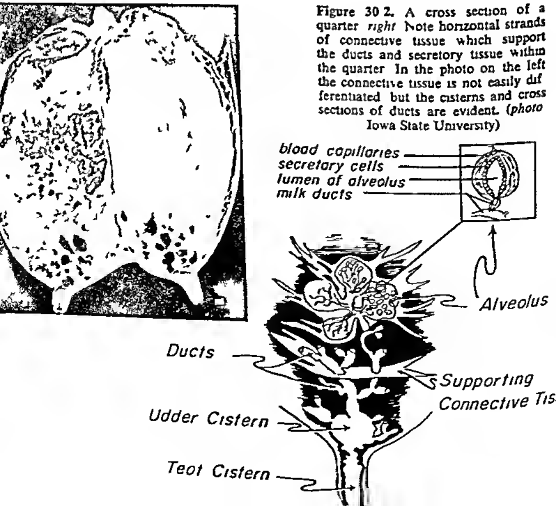


Figure 30 2. A cross section of a quarter *right* Note horizontal strands of connective tissue which support the ducts and secretory tissue within the quarter In the photo on the left the connective tissue is not easily differentiated but the cisterns and cross sections of ducts are evident. (*photo* Iowa State University)

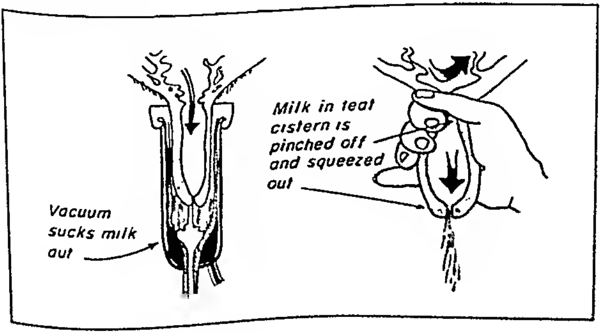
Note in the drawing that each duct is slightly constricted at the point where it joins a larger duct. These constrictions are opened or closed to control passage of the milk to the milk cistern. Each of the ducts acts as a storage cistern for milk until milking begins.

The teat is relatively hollow. The teat cistern connects directly with the large milk cistern at the base of the quarter. In some cows this connection is not as large and open as indicated in Figure 30-2. Overlapping layers of tissue at the top of the teat cistern sometimes slow milk flow into the teat and can slow the speed of milking.

The tissue lining the inside of the teat cistern may contain numerous "pockets." There is considerable variation among cows; in some the lining of the teat cistern is smooth. Where pockets exist it is possible that some milk might remain here and permit an increased bacteria count of subsequent milkings or cause infection.

Milk leaves the teat at milking time through the "streak canal." This opening is controlled by a circular, sphincter muscle. The sphincter muscle constricts the opening between milkings, but may relax some when the cow is washed for milking, so milking proceeds rapidly and easily. The relaxation of this muscle at milking is not complete, nor perhaps even noticeable. It is apparently a part of the whole "let-down" reaction resulting from a stimulus associated with milking. Milk is forced through the streak canal by pressure on the teat or the vacuum present in a milker teat cup (Figure 30-3). A sphincter muscle without sufficient tonus may permit milk to drip or flow from the teat as milk accumulates in the udder prior to milking, and especially when let-down occurs.

Figure 30-3. The milking process. Milk is forced through the streak canal by positive or negative pressure.



The anatomy of the udder also includes a profuse system of nerve cells, reaching the alveoli, each duct, and the teat. Let down of milk is closely and intricately controlled by the nervous system, stimuli for this nerve control are environmental happenings and/or hormones released into the circulatory system by endocrine glands at certain times.

30.2 Physiology of Secretion

Circulating fluids—blood and lymph—are the immediate source of milk constituents, or precursors of milk constituents. It has been estimated that 300 to 500 pounds of blood passes through the udder for each pound of milk produced.

Milk is produced in the alveolar cells of each quarter. Some of the milk components apparently *pass directly* into the cells from circulating fluids, through the wall of the capillary and the cell wall. Other milk constituents *are manufactured in* the alveolar cells, being synthesized from certain precursors supplied by the circulating fluids.

The average composition of milk produced by different breeds was given in Table 28-1, page 405. Water, which makes up most of the weight of milk, apparently enters the mammary tissue by simple filtration. Sources of other nutrients that milk contains are discussed in the following paragraphs.

Lactose, a disaccharide which is the major carbohydrate in milk, is composed of glucose and galactose. These two compounds are monosaccharides, rather similar in chemical structure. Since both blood and milk contain glucose, it might be assumed that glucose moves into the alveolar cells by simple filtration. This apparently occurs to a great degree, but research indicates that some of the glucose is also formed in the cells from other small compounds, such as lactic, butyric, and propionic acids.[2] Certain of these small acids are the major products of carbohydrate digestion in the ruminant, so the blood does contain significant quantities.

Galactose, the second monosaccharide in lactose, is apparently formed by a rather direct chemical conversion from glucose. This conversion is accomplished in the secretory cells with the aid of enzymes. One unit each of glucose and galactose then are chemically combined to form lactose.

Most of the protein in milk is in the form of casein, but some appears as lactalbumin and globulin. Each of these proteins contains different portions of amino acids linked in unique patterns. Most milk proteins are different from the blood proteins, so it is apparent that the alveolar cells have the major responsibility for building up the characteristic milk protein molecules.

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[2] J. M. Barry, "The Biochemistry of the Mammary Gland," *Endeavour*, XVIII, 173, 1959.

Research indicates that large proportions of the amino acids used for casein, lactalbumin, and globulin come directly from the blood. They were present in the blood as free, circulating amino acids. There is also evidence, however, that blood proteins and glycoproteins (compounds made of both carbohydrate and protein) *can* be absorbed into the mammary gland and used as a source of amino acids. In addition, it has been demonstrated that mammary tissue is capable of *synthesizing* certain dietary nonessential amino acids for milk protein formation.

A similar situation exists in the formation of milk fat. Many of the long-chain fatty acids which form a part of the milk fat are apparently absorbed directly from the circulating fluids. At least part of the short-chained fatty acids, however, are synthesized in mammary tissue from acetate (a small, two-carbon unit) or other compounds.

Minerals in milk are absorbed directly into the alveolar cells from blood. Some are present as free elements; others are in a combined form. It may be that some type of selective absorption occurs to control the amounts and proportions of the minerals in milk.

Vitamins, or their precursors, come directly from the blood. Since vitamin intake influences vitamin level in the blood, it also has an effect on the vitamin level in milk.

As milk is formed in the secretory cells, it passes into the lumen of the alveoli (Figure 30-2), then into the ducts for storage. As milk accumulates, the udder enlarges and pressure inside the udder increases.

Udder pressure influences rate of milk formation. As the udder fills with milk and pressure increases, milk formation slows. This explains why high-producing cows usually give more milk if milked three times per day.

Though pressure *influences* milk formation, it *doesn't control it completely*. Pressure inside the udder is often greater than in the blood system and absorption of milk constituents or precursors continues. The exact mechanism of this phenomenon is not fully understood.

Udder pressure may also explain why the last milk drawn from a cow often contains a higher proportion of fat than the first milk removed. The large fat particles are more likely to be retained in the individual secretory cells of the alveoli when the udder pressure is high, than the smaller particles or compounds, such as water, minerals, and carbohydrates. As the cow is milked, udder pressure decreases and the fat globules leave the cells and flow down through the duct system.

Cows vary in the degree to which fat is held in the secretory cells, but since the strippings of some cows contain about 2.5 times as much fat as the average of all the milk, it usually pays to milk cows out completely.

The physiology of secretion should probably include a brief discussion of normal let-down of milk at milking time, controlled by the nervous system. Let-down is apparently initiated by some stimuli that the cow

associates with milking If a cow is handled quietly and accustomed to the milking routine, she may respond to any one of several normal stimuli—sound of radio music as she enters the milking parlor, the feel of a warm wash cloth on her udder, presence of feed in her box, or other routine factors Dairymen normally develop an habitual pattern in the milking process and cows become adjusted to it. Any change in this pattern, such as a different person doing the milking, failure to wash the udder, etc, may interfere with the normal let down process The influence of hormones on milk let down is included in the next section

30 3 Hormonal Control

Development of the udder begins in the embryo, as hormones of the female sex organs are produced and circulate through the embryo At birth the teats on a heifer calf are evident and usually the udder is noticeable Between birth and sexual maturity the udder grows in size, mostly because of the development of supporting tissue Inside the udder the duct system develops near each teat. It is possible that the duct system may begin to develop even before birth These developmental processes, as well as those which occur later, are influenced directly and/or indirectly by the anterior portion of the pituitary gland, which secretes hormones

The anterior pituitary is mainly responsible for initiating the development of follicles on the ovary after puberty (see Chapter 13) The ovaries secrete estrogens which, in turn, may further promote udder growth and development The estrogens apparently influence the udder in two ways between puberty and pregnancy, (1) by stimulating the pituitary to secrete hormones which stimulate complete development of the duct system and the alveoli (groups of secretory cells) and (2) by increasing the blood supply to the udder This increased blood supply furnishes more nutrients needed for tissue growth and, of course, brings a greater supply of the hormones which are stimulating development.

Development of the ducts and alveoli continues during the first part of pregnancy The initiation of milk secretion the last day or so of pregnancy is apparently caused by some hormone combination, but the endocrine influence is not fully understood Tissues around the developing fetus produce more estrogen which, in turn, apparently stimulates the pituitary to produce lactogenic hormone to stimulate milk secretion Some factor or factors, however, seem to hold this lactogenic hormone in check until just prior to calving, when the heifer or cow begins to "make bag"

The pituitary exerts a strong influence on the mammary gland, through the lactogenic hormone, immediately after calving Milk production rises sharply, and seems to take priority for available nutrients (Figure 30-4) Some high producing cows are not able to eat enough feed to supply the requirements for milk production and lose weight during the first part of

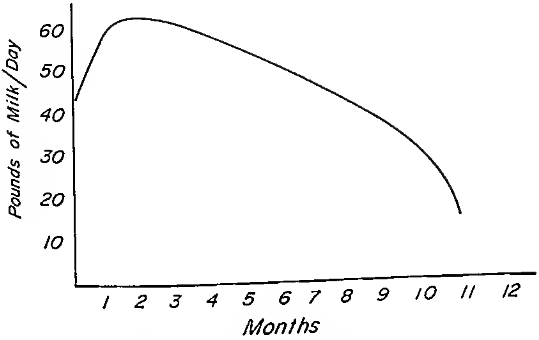


Figure 30-4. A typical lactation curve. Production usually reaches a peak about 45 days after calving, then declines. Low-producing cows reach a peak earlier.

lactation. As lactation proceeds, lactogenic hormone production decreases, milk production declines, and the pituitary has less influence on milk production. Production becomes more of a function of feed intake and, if feed is removed or limited, the cow dries up rather than losing weight.

There are many other influences of hormones on udder development and milk secretion which have not been discussed here. There are other endocrine organs and tissues, other hormones, innumerable interactions among endocrine tissues and hormones, as well as interactions among these and management practices. More complete discussions may be found elsewhere (see footnote, page 431).

Hormones may have a direct or indirect influence on milk let-down in preparation for milking. A cow that is quietly handled and accustomed to the normal milking routine begins to let down her milk when she receives certain stimuli associated with milking.

The let-down process is not simply a relaxation of the udder. Rather, the stimuli mentioned cause the pituitary gland to secrete a hormone, oxytocin, which *forces* milk from the alveoli and small ducts down into the larger ducts and milk cisterns. Muscles surrounding the alveoli *contract*, forcing out the milk. Muscles along the sides of the small ducts also constrict, shortening the ducts and widening the natural constriction present where each duct joins a larger duct.

Speed of let-down normally varies from about 15 seconds to one minute. Duration also varies, but is usually short enough that *rapid milking* is beneficial. Constricted muscles, mentioned above, gradually lose their

tonus and cease to force remaining milk down into the milk cisterns If cow is milked slowly, she may therefore give less total milk

Other hormones may sometimes *prevent* milk let down If the cow frightened or angered, her adrenal glands produce and secrete considerab adrenalin the 'fight or flee' hormone, into the circulatory system Adr nalin reaches the udder almost instantaneously, muscle fibers which woul otherwise contract to cause milk let down relax, and the cow 'holds up ber milk

30 4 Nutrition and Milk Composition

Under normal feeding and management programs the percentages o carbohydrate, protein, and fat in milk are not greatly influenced by th *composition* of the ration Restriction of one of these macronutrients u the ration may cause a sharp reduction in *volume* of milk produced bu will not alter composition appreciably In fact, lack of energy (mostl supplied as carbohydrates in grains and roughages) *is the most common limiting factor in milk production*

Numerous experiments have demonstrated that the *kind* of fat present in milk can be influenced, to a degree, by the kind of fat present in the ration High levels of extremely soft fats in the ration, *for example*, may cause the fat in milk to be slightly soft. Similar influences on protein and carbohydrate structure are not as common, apparently because of the way the precursors of these milk components are metabolized in the body and in the secretory tissue

The method of feeding or the mechanical form of the ration may influence milk composition Rapid changes in feeds may cause a temporary drop in production or butterfat percentage If the entire ration is finely ground, or ground and pelleted, the butterfat percentage may be low Metabolic reasons for these effects are not fully understood It may be that the mechanical form of the feed influences the proportions of fatty acids produced from carbohydrate digestion in the rumen and that this, in turn, influences utilization or production of fatty acids by the secretory tissue

Milk composition normally changes as lactation progresses (*Figure* 30-5) The protein and fat percentages are negatively correlated with volume of milk produced, content of these nutrients increases the latter part of lactation. The lactose percentage is *positively* associated *with* volume produced Reasons for these changes are not apparent.

There is little evidence that the level of minerals in a cow's ration (within reasonable limits) appreciably influences the mineral content of the milk. The percentages of calcium and phosphorus, present in large quantities in milk, are usually not *influenced* by the level in the ration If the ration is low in calcium or phosphorus, the cow's blood levels will

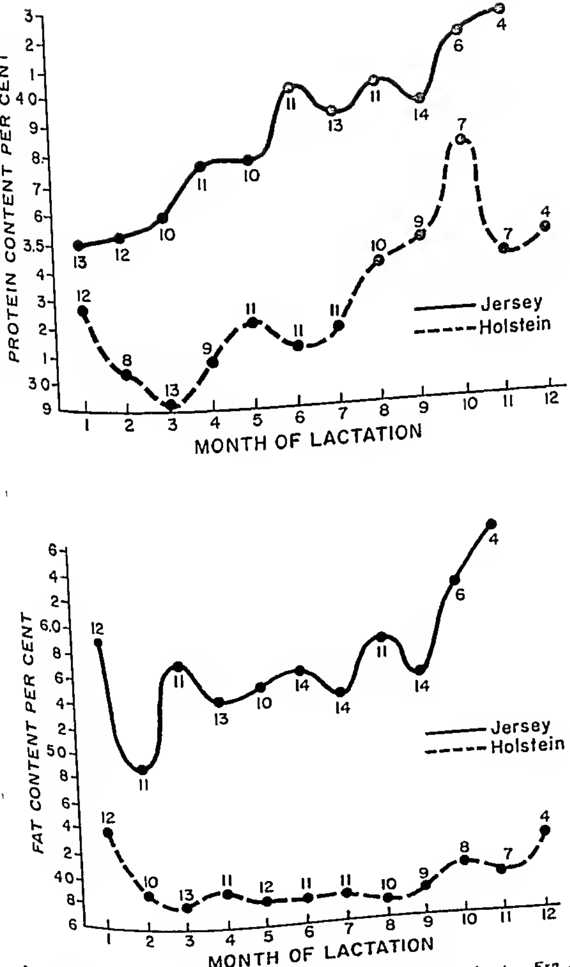


Figure 30-5. Changes in milk composition during lactation. (*Kentucky Agr. Exp. Sta. Bul. 667*)

decline and she will use considerable of these minerals stored in her skeleton before milk production declines

This does not suggest, of course, that dairymen needn t be concerned with the mineral level of a cow s ration Any decrease in milk production is costly Minerals removed from the skeleton for milk production must be replaced. And minerals perform other important functions in digestion and metabolism

The influence of ration on vitamin content of milk varies according to the vitamin In general, those vitamins which are dietary essentials for the cow—A, D, E, and K—are present in milk in somewhat the proportions they are present in the feed In the case of vitamin A, of course, some of the potency may be present as the precursor, carotene

The milk level of vitamins that are not dietary essentials—vitamin C produced in tissues and the B vitamins manufactured in the rumen—does not depend, of course, on the ration composition

Colostrum, the product of the mammary gland during the first few days after calving, is especially high in protein, fat, minerals, and vitamins A and C This is not necessarily a function of the ration but adequate levels of certain of these nutrients must be present. These high levels of critical nutrients help the young get off to a good start Some of the extra protein in colostrum is in the form of gamma globulin, which seems to function as a nonspecific disease fighter It makes the newborn animal more resistant to diseases and infections Colostrum also contains certain specific antibodies which further protect the nursing young

Recent research has indicated that specific antibodies *might* be produced in the cow and secreted in milk by exposing the cow to certain *human disease organisms* The theory is that milk might provide a simple and painless way of causing immunity to certain diseases of people It is not known if this technique will prove fully effective or practical.

With the use of numerous nonnutrient feed additives in livestock production, there is some concern over the movement of such compounds through the body and, perhaps, through the mammary gland into milk. Traces of certain fed or injected compounds such as antibiotics and stilbestrol have been detected in milk Federal regulations are designed to prevent sale of milk containing residues of many such additives

30.5 Flavors and Odors

The obscurity of flavor and the difficulty of appraising flavor of foods were mentioned briefly in reference to meat (Section 26 3) Variation in flavor might exist without distaste on the part of the consumer Also, certain people prefer different kinds or intensities of flavor than others

It is presumed that most of the flavors milk contains are either lipid in nature, or else they are fat soluble—carried in the fat portion of the milk.

Whole milk has more flavor than skim milk. Butter is used by many good cooks to enhance the flavor of cooked vegetables.

Most off-flavors in milk, which are due to ingested or inhaled materials, are probably volatile fatty acids that become a part of the milk fat. Flavors that result from processing milk would not necessarily be due to the fat. Overheating of protein or carbohydrate, or other factors, may contribute to an off-flavor. Oxidized flavor, however, which results when milk is exposed too long to the sun and/or air, is probably mostly due to oxidation of short-chained fatty acids.

Long lists of feeds which will alter the flavor and odor of milk have been compiled. Most such feeds are not available to dairy herds, especially as more cows graze nonpermanent pastures or are fed in confinement. There are, however, certain common feeds used in these current management systems that can impart distinct flavors to milk.

Early in the spring when many cows are turned out on lush, rapidly growing pasture, milk sometimes has a "grassy" flavor. This flavor "disappears" after a few weeks, as the grasses mature. The cow may also develop the ability to degrade certain of these flavors before they reach the milk, and it may be that consumers gradually become accustomed to the flavor. This grassy flavor is of less significance as a larger percentage of herds in each milkshed (area supplying a particular market) are fed in confinement.

Rape, a member of the cabbage family, or wild onions, will impart a distinct flavor in milk. Sweet clover and rye also sometimes produce a characteristic milk flavor. Bromegrass, which has become very popular as a forage for dairy cattle, influences the flavor of milk in certain seasons.

Flavors in milk that are due to feed are most evident if the cow grazed or consumed the feed one or two hours prior to milking. Some flavors reach the mammary gland in a few minutes, but the greatest concentration is reached after an hour or two elapses. After this, the concentration of the flavor in milk decreases as it diffuses back into the blood for detoxification and elimination or is degraded by mammary tissue. It is therefore worthwhile to feed cows immediately *after* milking, if the feeds are suspected of potentially influencing milk flavor, and to bring cows in from early spring pastures two or three hours before milking.

There is apparently a significant difference among cows in their tendency to impart feed flavors to milk or, conversely, to degrade volatile flavor compounds before they reach the mammary system. It is conceivable, therefore, that selection for absence of feed flavors might be accomplished.

Feed and other flavors might reach the milk by other routes than the digestive tract. Since most noticeable flavors are highly volatile, they can be inhaled and reach the circulatory system via the lungs. This emphasizes the importance of barn ventilation.

Certain processing techniques are rather effective in removing the volatile flavors in milk Most, as would be expected, involve the principles of heating and/or subjecting the milk to a vacuum Both conditions make evaporation easier, so the volatile compounds are caused to escape as gas into the atmosphere

30.6 Milk Appearance

The most noticeable difference in milk appearance is the color variation associated with breed Guernsey and Jersey milk are more yellow Milk of most other breeds is almost white The yellow color is caused primarily by carotene, which is a precursor of vitamin A, and other yellow pigments contained in grass, hay, silage, yellow corn, and certain other feeds Most Holsteins, Ayrshires, and Brown Swiss do a very efficient job of converting carotene to *colorless* vitamin A, primarily in the wall of the small intestine and in the liver, so their milk is not so yellow Most Guernseys and Jerseys, however, do not convert much carotene to vitamin A, so the yellow pigment passes directly to the milk There is little difference in vitamin A *potency* of the milk from the different breeds, as far as the human who consumes the milk is concerned If the cow doesn't convert carotene to vitamin A, the job is done in the body of the consumer

Season and kind of feed may influence milk color In early spring, when grass is lush and the pigment content is high, milk will be yellower The effect is striking in breeds which are inefficient in carotene conversion, but also noticeable in other breeds because they do not convert all yellow pigments As the season progresses, Guernsey and Jersey milk remains yellow longer, probably because they draw from the yellow pigments stored in body fat Green chlorophyll in forage is used as an indicator of carotene and other yellow pigments The green color masks the yellow, but the content of each is high in early spring and periods of rapid growth, and lower in late summer

If cows are fed weathered, bleached roughage, grain sorghum, and soybean meal as the main feeds, the milk would be almost pure white Vitamin A might be supplied in pure form, so would not contribute to the color of the milk Such a ration is not recommended because the roughage would be unpalatable and poorly digested Most good dairy rations include top quality roughage so considerable pigmentation is automatically supplied

30.7 Udder Injuries and Infections

Incidence of udder injuries and infections are closely associated with efficiency of milk secretion. It was previously mentioned that permanent loss of a quarter causes some increase in size and productivity of the remaining quarters, but that total production is still somewhat reduced

This development of remaining quarters takes considerable time and is of no significance when one teat or quarter is *temporarily* infected or injured.

Tendency toward injuries may be inherited to a degree since injuries are highly associated with closeness of the teats and udder to the ground. If the udder attachment is poor, the teats might almost drag. They can be cut by weeds and brush in pastures, catch splinters on door sills, or even be stepped on. If the middle suspensory ligament is weak and the middle of the udder drops so the teats point out, they might be kicked and bruised as the cow walks.

Tendency toward udder infections might also be inherited and associated with conformation or structure of the udder. Teats that are continually dirty have a better chance of becoming infected. Dirt *and* injury multiply the chances. The heritability of mastitis resistance is about .25 (Table 15-1, page 211). Further evidence that susceptibility to mastitis infection is partly inherited is the repeatability value of .35 to .40, given in Table 29-3. The same cows tend to have mastitis in successive seasons, though environment varies considerably from season to season.

Infection of or injury to the udder of a young heifer may limit her milk production as a cow. If scar tissue develops in place of some of the secretory tissue, less milk can be produced *and* less milk can be stored in the udder between milkings. Overfeeding of heifers during growth may decrease the milk producing capacity of the udder by causing deposition of nonsecretory tissue.

Infections can be spread easily among cows in a milking herd. Increases in herd size and confinement feeding contribute to spreading of disease unless sanitation is rigid. Most infections are still spread, however, during the milking process by the machine or the man. Here the importance of *high quality labor* becomes evident. Teats should be checked for injuries and treated. Each quarter should be routinely checked for mastitis by use of a strip cup. The first milk from an infected udder is usually thick and clotted, so catches on the screen of a strip cup (see Figure 31-3, page 448). All equipment should be thoroughly cleaned before the next cow is milked.

Drugs that are used for treating udder infections and injuries should be used wisely. Obviously milk from infected quarters is not included in market milk. Also, if the quarter is treated by some medicant, milk from that quarter should not be sold as long as a residue of the medicant is present in the milk. If treatment is by injection, all quarters are affected.

Sanitation is the primary consideration in milking facilities because selling milk *depends* on meeting sanitation requirements Most laws which govern milking and milk handling equipment and procedures are *city ordinances* There is, therefore, much variation in sanitation rules and regulations

This may seem unusual, compared to the Federal Meat Inspection Division which checks meat processing facilities and procedures in most large plants The reason for the difference is probably historic and influenced by the nature of the product and marketing patterns Packing centers developed in large cities Meat was packed in barrels, or refrigerated in later years, and shipped across state lines This gave the federal government authority and responsibility to specify processing procedures to insure a high quality product Most milk, however, was bottled and sold locally To protect local consumers, city ordinances developed As cities grew, milk was purchased from distant areas *if* it met *sanitation* requirements of that city

Sanitation ordinances may specify, for example, (1) that all cows be certified free of tuberculosis and other such diseases, (2) space requirements per cow, in loose housing or stanchions, (3) distance between loose housing and milking parlor, (4) that the milking parlor be separated from feed storage, (5) that the inside of the milking barn or parlor be painted white, (6) that the *milkhouse* be equipped with a screen door and screened windows, (7) that ample water and floor slope be provided for cleaning, (8) that water used for cleaning equipment be below a certain bacteria count, and (9) maximum temperature of the milk when loaded and when it reaches the plant. All such specifications are aimed at producing clean, wholesome milk with a low bacteria count

In some parts of the United States milk is produced and marketed under various grade specifications Grade A milk is produced under more rigid sanitation rules Rules for producing and marketing Grade B milk are less rigid and the milk can have a higher bacteria count when it reaches the plant Most Grade B milk is destined for manufacturing of dried *milk* and similar products There is a wide price differential between the grades (Figure 31-2)

Grade specifications for market milk have much less significance now, as most commercial dairymen are equipped to produce and handle milk according to very rigid (Grade A) sanitation rules and most large markets will accept only Grade A milk, *regardless* of whether it will be used as fluid milk or for manufacturing Also, feed and labor costs in milk production, coupled with relatively low prices for Grade B, make the production and marketing of this quality of milk economically impractical

Presently most milk is marketed *under* a *classification* system according to what the milk will be *used* for (see Section 31 5)

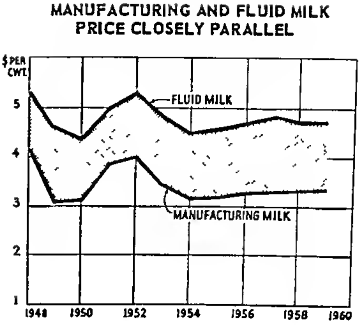


Figure 31-2. There is a wide price differential between milk purchased for fluid use and that purchased for manufacturing, even though it may be the same quality. (National Milk Producers Federation)

31.2 Use of Machines

Hand milking on commercial dairy farms is history, except for special cases. Many different kinds of machines are used, varying in type, cost, and effectiveness. In most milking parlors and in some stanchion barns only the teat cup assembly is carried from cow to cow. Permanent pipe installations supply vacuum and carry the milk to the cooler and storage. Otherwise, the milker pail may be suspended under the cow by a strap, or set on the floor between cows or in the alleyway.

A good milking machine must (1) be easily cleaned—smooth finish and construction, rust-proof, etc., (2) provide uniform vacuum, (3) not creep up on the teats, and (4) provide some massaging of the teat between "pulls" so blood doesn't accumulate in the teat.

The first step in the milking procedure is to wash the udder. This usually provides the stimuli needed to cause let-down of milk. A few squirts of milk are then drawn from each teat into a strip cup (Figure 31-3). This may further encourage the let-down reaction, but is done primarily to check for infected quarters. Also, the first portion of milk is usually higher in bacteria count, having been held near the streak canal.

Clean teat cups are then attached to the udder. It is important that the cow milk out quickly for maximum milk yield. Let-down involves muscle tonus and the muscles tend to lose their tonus after a few minutes. As soon as the cow is milked out, the teat cups are removed. In some cases it is worthwhile to pull down on the teat cups or massage the udder a bit near the end of milking to be sure the last of the milk (often higher in fat percentage) is removed.

The milking process becomes habitual. Both the dairyman and the cows become accustomed to a standard routine. A dairyman who works

31

MILK HANDLING AND MARKETING

This chapter is devoted to handling and distributing milk, from the time the cows are milked until the milk reaches the consumer. It includes discussions of sanitation ordinances, milking facilities, cooling and storage, equipment, marketing procedures and regulations, and consumption of dairy products.

Because milk is a relatively perishable food, and because a high percentage is consumed in a relatively natural state, handling of milk to preserve its natural and desired characteristics is very important. Milk must be produced in a clean environment using clean equipment. It must be cooled, processed, and distributed to consumers in a rather short time. Where involved processing occurs, as in production of ice cream, cheese, or butter, more time elapses but the processing must be initiated and completed before quality of the milk is impaired.

31.1 Milking Facilities

Facilities must (1) meet rigid sanitation requirements, (2) make efficient use of labor, (3) be flexible, (4) be economical, and (5) keep the cows comfortable and sheltered so production is not limited. Any discussion of milking facilities on dairy farms automatically includes consideration of housing for the herd. The two common systems for handling dairy herds are (1) permanent stanchions for all cows and (2) a milking parlor (Figure 31-1), with "loose" housing for the herd.

The effectiveness and success of either system depends primarily on the management ability of the dairyman. Each has advantages and disadvantages. Certain comparisons have shown little difference in milk production or efficiency of feed utilization. Almost twice as much bedding is usually required with loose housing in order to keep the cows dry and clean. Considerably less labor is usually required, however, with loose housing and a milking parlor. Feeding can be arranged to require less labor, cleaning can be accomplished with large, power equipment, and the milking process can be more efficient—one man can milk more cows at one time in most parlors.

Udder and teat injuries, as well as other injuries, are greatly reduced with loose housing. Construction costs are much less and the loose housing

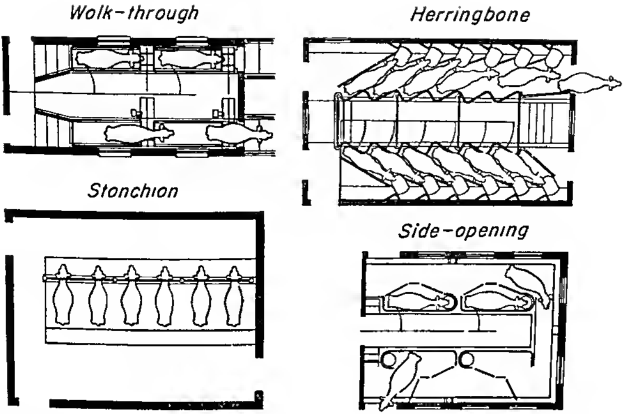


Figure 31-1. The most common types of milking parlor arrangement. (Barn Equipment Association)

system is more flexible. If the herd is increased, only the cheaper shelter need be expanded; the parlor can be used more hours. If the herd is decreased in size, the shelter can be used for other purposes.

Table 31-1 presents estimated relative cost and efficiency figures for different types of milking parlor systems. Not all types are included and the figures cannot necessarily be applied to all situations.

It is recognized that many farms now have well-built barns with many stanchions. To convert to loose housing costs money and involves a change in the dairyman's habits and routine. Such changes might be practical, however, primarily because of lowered labor needs. Changes to loose housing and milking parlors may become more practical as pressure is exerted to expand herd size.

Table 31-1. Investment and Labor Required in Milking-Parlor Systems*

Type	Investment			Minutes of labor per cow
	Building	Equipment[1]	Total	
Four-cow stanchion	$2,273	$1,436	$ 3,709	3.16
Three-cow side entry	3,576	2,275	5,851	2.61
Six-cow side entry	5,972	3,422	9,394	1.71
Twelve-cow herringbone	5,445	5,122	10,567	1.09

*Randolph Barker *et al.*, *Iowa Farm Sci.* 14:318, 1959.
[1]Bulk tank not included.

Figure 31-3 Drawing the first squirts of milk into a strip cup (DeLaval Separator Company)

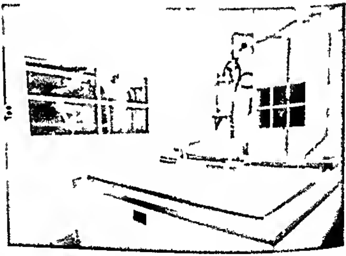


Figure 31-4 An increasing percentage of milk is handled in bulk considerably reducing labor costs (Iowa State University)

quietly and swiftly, making every motion count, can make very efficient use of his labor

31 3 Cooling

Milk must be cooled *rapidly* down to about 35° F, to prevent rapid multiplication of bacteria and souring With bulk handling of milk, most coolers are made of stainless steel These coolers are easily cleaned and will not rust. In 1960 about 65 per cent of the milk supplied to federal order markets was cooled in bulk tanks (Figure 31 4)

Milk piped from the milking parlor is sometimes routed over refrigeration coils which lower the milk temperature almost instantaneously Such equipment is not allowed in some market areas because of difficulty in keeping the coils clean

Where cans may still be used for storing and hauling milk, the full cans are usually cooled in a water-filled, metal, refrigerated cooler Since the cans are immersed in water at about 32° F, cooling is very rapid and effective

31.4 Care of Equipment

Sanitation is emphasized again, bacteria multiply rapidly in equipment that is not clean All equipment must be designed and installed with ease and effectiveness of cleaning in mind If pipes in pipeline systems are to be cleaned "in place," all junctions must be perfectly smooth so milk residue cannot accumulate in cracks and joints Otherwise all pipes should be disassembled for cleaning

The water supply for cleaning and rinsing should be checked More than once a high bacteria count in milk has been traced to a contaminated source of rinse water

The first step in cleaning dairy equipment is usually flushing with cold water This must be done *immediately* after the equipment is used or, in the case of the bulk tank, emptied Cold water is more effective than hot water, hot water tends to solidify milk particles and they settle out or stick Detergents are then used for cleaning They lower the surface tension markedly so are very effective Equipment is then rinsed, usually with very hot water, to remove traces of the detergent

On many dairy farms the teat cups are rinsed in cold water, detergent, and hot water between cows This is worthwhile to help prevent spread of disease

31.5 Marketing Milk

Most dairy farmers sell their milk by one of three major routes, through cooperative marketing associations, direct to processor, or direct to consumer In the latter case the producer also does the necessary processing and sells through roadside stands, by farm pickup, or local delivery routes Other methods of marketing involve only a small proportion of the milk

Most of the separated cream that is sold by dairymen goes directly to a processor Much less separated cream is sold now than formerly and most milk produced on farms is sold as whole milk (Figure 31-5)

Cooperative milk marketing associations handle most of the milk Such associations have existed for half a century in certain areas They apparently provide the producers more bargaining power, since an association might control most of the milk produced in the area The association

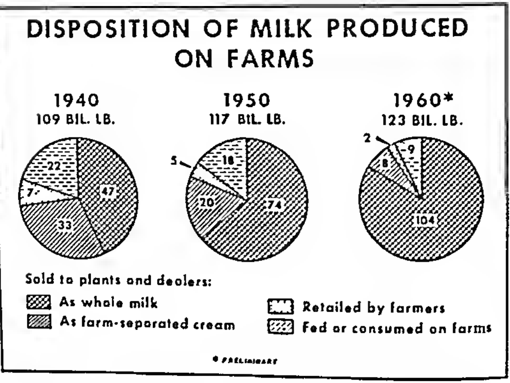


Figure 31-5. Most milk leaves the farm as whole milk. This is usually more practical than selling cream and feeding the skim milk. (AMS, USDA)

can afford to hire experienced people to deal with prospective purchasers and also to help producers with production and sanitation problems.

Milk production is seasonal (Figure 31-6); consumption is less seasonal. During periods of surplus production not all milk can be used for fluid milk sales; some must be routed for manufacturing. Without cooperatives, processors would cease to purchase from some producers, or would buy milk from certain producers at a much lower price, for manufacturing. With cooperatives, a portion of the total supply can be classed as manufacturing milk in peak seasons and each producer therefore sells some milk at a lower price.

Most milk marketing associations have developed around large population centers. They have a board of directors, officers, and a central office. Some operate a receiving station where milk is collected, then sent to processors. Others route incoming trucks directly to processors.

Presently much milk marketing is carried on under "federal milk marketing orders."[1] These orders are an evolution of previous cooperative efforts in milk marketing. The expressed purpose of a federal order is to promote and maintain orderly milk marketing conditions for dairy farmers and to assure consumers an adequate supply of pure and wholesome milk. Provision for such orders was made by the Agricultural Marketing Agreement Act of 1937.

[1] AMS, USDA, *Agricultural Situation*, 43:11:10, Nov. 1959.

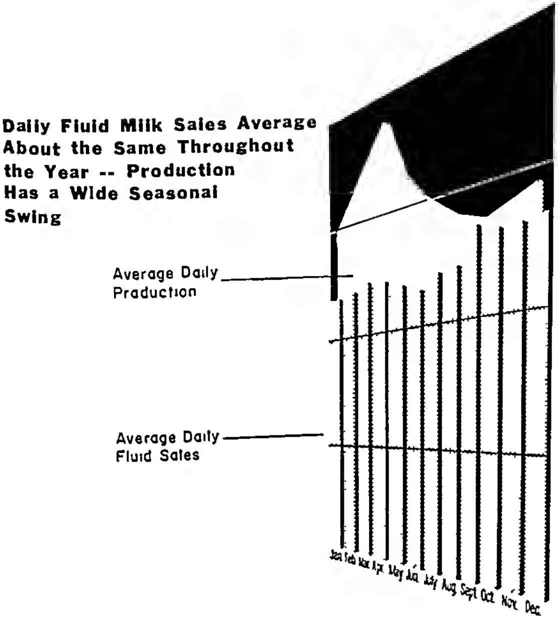


Figure 31-6. Seasonality in milk production. With confinement feeding of good forage and year-round calving the production of milk is levelling out. (National Milk Producers Federation)

The orders are issued by the Secretary of Agriculture at the request of producers (usually through a cooperative association) and with the approval of two thirds of those farmers who supply a market with milk.

Each order may be different, but all contain a provision for establishing minimum prices that processors must pay producers for milk of each use classification. Second, all milk is pooled so that farmers share equitably in the higher price received for milk that is used in fluid form as well as the lower prices received for manufacturing milk.

Processors or handlers of milk must pay the minimum prices, calculated from provisions of the order, for each use classification, make accurate weights and tests, and account for the way the milk is used. The order

does not control how much the processor can buy, from whom, or at what prices he may sell Farmers may produce and sell any amount of milk they wish under a federal order and may sell to anyone they wish, independently or through a cooperative

In September 1960, federal milk marketing orders were operating in 80 fluid milk marketing areas, in which over 78 million consumers reside (Figure 31-7) About 2200 processors handle the milk in these markets

Where milk is classified according to use and for pricing purposes, the class designations may differ among areas, such as

Northeastern U.S	*Parts of the Midwest*
Class I —Fluid Milk	Class I —Fluid milk and cream
Class II —Cream	Class II—Manufacturing milk
Class III—Evaporated Milk	
Class IV—Butter and Cheese	

Since milk production is higher in the spring, a larger percentage of milk is diverted to manufacturing, and so is classed accordingly See Figure 31-6 for a yearly average of how milk is used

Changes in the dairy processing industry have influenced the marketing of farm produced milk There are fewer processing plants and those which exist handle more of the product (Section 2 8) This centralization of processing means there is no fluid milk or cream plant in many small towns, as there formerly was

31.6 Milk Pricing

Milk prices paid to producers are usually quoted on a hundredweight basis The average price per cwt. that a processor pays may be determined by (1) supply and demand—the competitive price required to attract milk to the plant, (2) a price set by bargaining between the processor and a producer association, or (3) a price determined by some previously agreed upon formula, as in federal order markets

This average price (often called ' blend ' price in federal order markets) would be paid for milk of a specified composition Milk containing a higher percentage of solids (dry matter) would bring a higher price per cwt., milk containing a lower percentage of solids would bring a lower price

To date the simplest and lowest cost technique for estimating the percentage of total solids in a batch of milk is to determine the percentage of fat. Within the range that normally exists in market milk, an increase of 0 1 per cent fat is associated, on the average, with a 0 04 per cent increase in non fat solids

This fact is considered in pricing techniques employed in many milk markets The value, to the processor, of each 0 14 pound of total solids

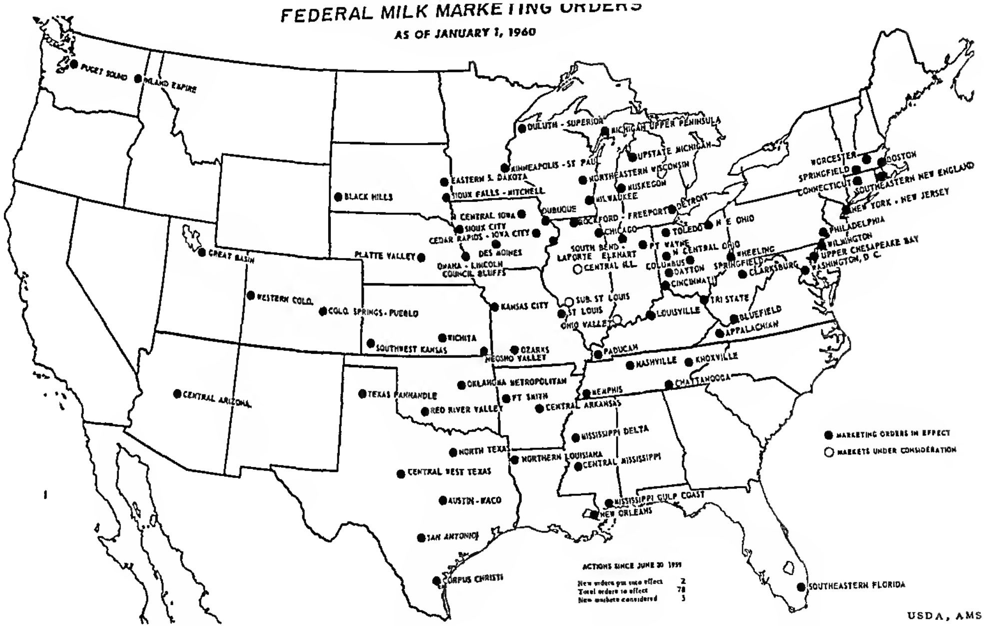


Figure 31-7. Markets operating under federal milk marketing orders, January 1960. Some

	Butter	Nonfat powder
Price per lb finished product	65 0¢	16 0¢
Less manufacturing costs[1]	- 3 5	- 4.0
Net value per lb finished product	61 5¢	12 0¢
Multiply by lbs of product produced from 0 14 lbs solids	× 121 lb	× 041 lb
Value to processor	7 422¢	0 491¢
Differential (value of 0 14 lbs solids)	7 9¢	

[1] Manufacturing costs do not include receiving pasteurizing and other costs associated with volume rather than with percentage of solids

Figure 31 8 An example of calculations used to arrive at a "differential" (Adapted from *Wisconsin Agr Exp Serv Circ 449*)

(0 10 pound of fat and 0 04 pound of non fat solids) is established This value is calculated and is based on current price of butter and non fat milk powder, manufacturing costs of these two products, and the fact that 0 10 pound of fat will yield 0 121 pounds of butter and 0 04 pounds of non fat solids will yield 0 041 pounds of non fat powder (Figure 31-8)

The differential is added to the previously mentioned blend' price per cwt for each 0 1 per cent the milk exceeds the specified fat content, or dedu ted for each 0 1 per cent the milk is below the specified fat content.

If the blend price at a market were established at $3 75 per cwt. for milk testing 3 5 per cent fat, milk testing 3 6 per cent would be worth $3 829 per cwt ($3 75 + 079 = $3 829) Milk testing 3 4 per cent would be worth $3 671 per cwt. It is emphasized that this method of calculating a differential *gives credit to both fat and non fat solids* in milk

It is recognized that there is herd variation and that 0 1 per cent in crease in fat content is not always associated with 0 04 per cent increase in non fat solids content. To the extent that this is true, the method described permits inequity in milk pricing

More equitable pricing may come with development or refinement of techniques for measuring non fat solids Most present methods are based on specific gravity (density) of fluid milk, and are not widely used be cause of cost time or precise environmental conditions required for accurate measurement An ultrasonic instrument which determines the percentages of both fat and non fat solids by measuring velocity of sound through milk at certain temperatures has been developed,[2] and may be

[2] W C Winder N P Cons gny and B Rodriguez-Lopez, "An Ultrasonic Method for Measurement of Sol ds-Not Fat and Butterfat in Fluid Milk. II An Evaluation of the Method." Presented at 56th annual meeting of the Am Dairy Science Assn. June 13 1961

refined for routine use at plants that handle considerable amounts of milk.

31.7 Consumption Trends

Trends in per capita consumption of dairy products are indicated in Table 31-2. Major changes are the decrease in consumption of butter and marked increases in per capita ice cream and cheese consumption. Intake of fluid milk per person has remained rather constant.

Table 31-2. Per Capita Consumption of Dairy Products, Pounds

	Average 1935-39	Average 1947-49	1959	1961
Total milk fat solids	31.7	29.6	25.0	24.0
Total nonfat milk solids	39.6	46.2	44.1	43.0
Cheese	5.6	7.0	8.1	8.5
Condensed and evaporated milk	16.8	20.1	14.3	13.3
Fluid milk and cream	330.0	359.0	330.0	314.0
Ice cream	9.9	18.7	18.7	18.1
Butter	17.0	10.8	7.9	7.4

*AMS, USDA, *National Food Situation*, February 1962

The decline in per capita consumption of *total milk fat solids*, shown in Table 31-2, is less than the decrease in butter consumption. In other words, there was an increase in use of butterfat, other than that in butter. The increased acceptance of margarine during the last decade as a spread and for cooking is no doubt the major reason for decreased butter consumption. Now nearly all states allow sale of colored margarine; formerly many prohibited it to protect the dairy industry. The price differential between butter and margarine has widened, so there is more incentive for low income families to use margarine. Though the price difference is greater, there is apparently less "prestige" difference between the products. The decrease in butter use may encourage pricing of fluid milk on a total solids basis.

Though consumption of non-fat milk solids has increased steadily in recent years, production still exceeds demand for human use. Therefore, considerable is diverted to livestock feeds, exports, and other uses (Figure 31-9).

Of the milk sold by farmers in 1960,[3] about 47 per cent went for fluid use, 26 per cent was used for butter, 12 per cent for cheese, and 8 per cent for frozen dairy products.

Other trends are evident in use of dairy products. Some people consume

[3] AMS, USDA, "The Dairy Situation," April 1961.

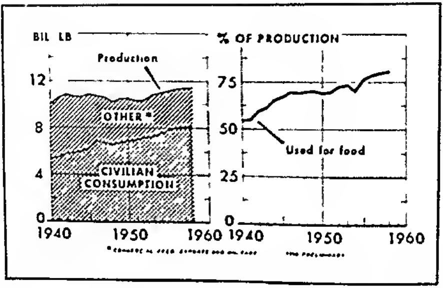


Figure 31-9. Production and use of non-fat milk solids since 1940. Production continues to exceed human consumption. (AMS, USDA)

more skim milk and less whole milk. Emphasis on low calorie diets to prevent obesity and heart disease, as well as a desire to keep a trim figure, have caused people to avoid some of the fat in the diet. Skim milk supplies the protein, carbohydrates, and B vitamins of milk. Because vitamins A and D are removed with the fat, these vitamins are usually added in purified form. Some dairies merchandise special low-fat milk, usually containing about one per cent fat and fortified with vitamins. Some consumers prefer this type of product to skim milk, perhaps due to the flavor contributed by the fat or perhaps due to the low prestige rating of skim milk.

There is also some trend toward low-fat frozen dairy products. The popularity of roadside drive-in stands featuring various forms of such products testifies to this. Such products are also available in quart and half gallon containers in super markets for home use.

Technological developments and progressive merchandising have helped expand the use of cheese. A wide variety of cheeses are available in small packages—in self-service display counters, featured for Christmas gifts (Figure 31-10), and promoted for use in spreads, salads, and cooked foods. Cheeses are used more for variety, which the American consumer now feels he can afford, than to supply needed protein as a meat substitute. Recognize, however, that cheese is a highly nutritious food, rich in high quality protein.

Considerable dry non-fat or whole milk solids are used for manufactured foods, such as pancake, muffin, and cake mixes, cereals, cookies, crackers,

it sponsors newspaper, magazine, radio, and television advertising The association has cooperated with producers and processors of other foods for promotional purposes Full color ads featuring cottage cheese and peach salads, milk and cookies, or other combinations have been widely and effectively used The American Dairy Association parallels the National Livestock and Meat Board and the American Meat Institute in its functions and financing

In most states in which dairy production and processing are significant industries, state dairy associations promote dairy products in cooperation with the American Dairy Association and other groups Funds may be obtained by donations, voluntary deductions from milk or cream checks, or a tax allowed by the state legislature and voted by a majority of the dairy producers

In some cases county or district dairy associations promote dairy products at a local level One county association promises a five dollar prize to the waitress who suggests milk to a "mystery diner" Members visit restaurant operators, encouraging them to include milk in the price of their meals, serve only butter for spread, use butter in cooking, and so forth

Some breed associations have been very active in dairy product promotion The trademarks "Golden Guernsey" and "All-Jersey" are common to many consumers Both exploit the richness and flavor of their milk and the bright, rich, yellow color (see Section 30 6) Association employees work closely with retailers, offering display and merchandising suggestions Some dairies handle only milk of one of these breeds Milk of other breeds is not as distinguishable, therefore not adapted to trademark promotion Other associations do, however, have their own promotional programs and cooperate with other groups in promoting dairy products

31.9 Dairy By-Products

Many dairy by-products such as dried skim milk, whey, and dried buttermilk are used as livestock feed ingredients See Table 6-4 for nutrient composition of these feeds

Dried skim milk, with only the water and fat removed, is very high in protein and highly digestible The protein is high quality, containing high levels of critical amino acids, so dried skim milk is valuable in feeds for non ruminants—pigs, chickens, and calves Dried buttermilk is similar in composition and value

Whey, a by product of cheese manufacturing, is rather low in protein, but the protein is high quality Whey is high in digestible carbohydrate and especially high in B vitamins Cheese is produced by fermentation caused by microorganisms These microorganisms produce high quantities of B vitamins, some of which end up in the cheese, but the whey also has

a high concentration. Certain kinds of whey are also credited with having certain "unidentified growth factors" for livestock or poultry.

Other miscellaneous dairy by-products such as cheese rinds, outdated fluid milk, and liquid whey also are used for livestock feeding. The use of dairy by-products in human foods was discussed briefly in Section 31.6.

APPENDIX

(Appendix tables do not include data for Alaska and Hawaii. Statistical data for these states are not yet generally available from the USDA.)

Rank	All cattle and calves		Beef cattle and calves (cattle not for milk)			
			Total		Beef cows 2 years and over	
	State	Number (thousands)	State	Number (thousands)	State	Number (thousands)
1	Texas	9,680	Texas	8,712	Texas	4,490
2	Iowa	6,654	Iowa	5,250	Oklahoma	1,822
3	Nebraska	5,414	Nebraska	4,911	Nebraska	1,569
4	Kansas	4,881	Kansas	4,300	Kansas	1,383
5	Wisconsin	4,339	Oklahoma	3,230	South Dakota	1,327
6	Missouri	4,304	Missouri	3,195	Missouri	1,240
7	Minnesota	4,258	South Dakota	3,053	Montana	1,120
8	California	4,232	California	2,836	Iowa	1,028
9	Illinois	3,882	Illinois	2,829	California	858
10	Oklahoma	3,854	Colorado	2,130	Louisiana	851
11	South Dakota	3,460	Montana	1,990	Mississippi	838
12	Colorado	2,333	Minnesota	1,943	Colorado	603
13	Ohio	2,249	Mississippi	1,501	Florida	713
14	Kentucky	2,242	North Dakota	1,445	Illinois	895
15	New York	2,174	Louisiana	1,407	North Dakota	694
16	Montana	2,112	Indiana	1,400	Alabama	691
17	Mississippi	2,107	Kentucky	1,398	New Mexico	669
18	Indiana	2,103	Florida	1,272	Kentucky	828
19	Tennessee	1,991	Alabama	1,269	Tennessee	573
20	Pennsylvania	1,971	Tennessee	1,205	Oregon	572
21	North Dakota	1,881	Oregon	1,157	Arkansas	569
22	Louisiana	1,818	New Mexico	1,155	Wyoming	550
23	Michigan	1,752	Georgia	1,128	Georgia	540
24	Alabama	1,689	Ohio	1,128	Virginia	403
25	Florida	1,598	Wyoming	1,079	Idaho	397
26	Georgia	1,481	Arkansas	1,014	Minnesota	383
27	Oregon	1,435	Idaho	983	Indiana	382

Table 1. Rank of States in Number of Cattle and Calves on Farms, January 1, 1962*

Rank	All cattle and calves		Beef cattle and calves (cattle not for milk)			
			Total		Beef cows 2 years and over	
	State	Number (thousands)	State	Number (thousands)	State	Number (thousands)
28	Virginia	1,422	Arizona	957	Arizona	355
29	Arkansas	1,374	Virginia	840	Washington	311
30	Idaho	1,359	Washington	830	Nevada	280
31	Washington	1,268	Michigan	597	Ohio	272
32	New Mexico	1,221	Wisconsin	546	Utah	269
33	Wyoming	1,126	Utah	531	North Carolina	211
34	Arizona	1,041	Nevada	499	South Carolina	191
35	North Carolina	907	Pennsylvania	439	West Virginia	169
36	Utah	898	North Carolina	433	Wisconsin	130
37	South Carolina	553	South Carolina	371	Michigan	117
38	Nevada	532	West Virginia	332	Pennsylvania	100
39	West Virginia	530	Maryland	152	Maryland	50
40	Maryland	498	New York	148	New York	46
41	Vermont	445	Maine	28	Maine	9
42	Maine	200	Vermont	19	New Jersey	5
43	New Jersey	196	New Jersey	15	Delaware	4
44	Massachusetts	153	Delaware	12	Vermont	4
45	Connecticut	150	Massachusetts	11	Connecticut	3
46	New Hampshire	101	Connecticut	10	Massachusetts	3
47	Delaware	54	New Hampshire	8	New Hampshire	2
48	Rhode Island	20	Rhode Island	1	Rhode Island	---
United States		99,500		69,695		28,111

*ERS, USDA, *Livestock and Meat Situation*, March 1962.

Rank	Milk cows 2 years and over		All sheep and lambs		Number of pigs saved[1]	
	State	Number (thousands)	State	Number (thousands)	State	Number (thousands)
1	Wisconsin	2,402	Texas	5,832	Iowa	20.205
2	Minnesota	1,435	Wyoming	2,220	Illinois	12,512
3	New York	1,393	California	1,959	Indiana	7,864
4	Pennsylvania	988	Colorado	1,932	Missouri	6,645
5	Iowa	925	South Dakota	1,711	Minnesota	6,408
6	California	881	Iowa	1,583	Ohio	4,530
7	Ohio	742	Montana	1,576	Nebraska	4,480
8	Missouri	723	Utah	1,258	Wisconsin	3,863
9	Michigan	708	New Mexico	1,191	South Dakota	2,783
10	Illinois	629	Idaho	1,113	Kentucky	2,323
11	Texas	604	Minnesota	1,024	Georgia	2,201
12	Kentucky	549	Ohio	977	Kansas	2,103
13	Tennessee	537	Kansas	880	Tennessee	2,058
14	Indiana	403	Oregon	851	North Carolina	2,016
15	Virginia	378	Nebraska	733	Texas	1,484
16	Mississippi	376	Missouri	726	Alabama	1,483
17	Kansas	374	North Dakota	715	Michigan	1,279
18	Nebraska	340	Illinois	711	Virginia	966
19	North Dakota	299	Arizona	520	Pennsylvania	773
20	Vermont	294	Indiana	503	Mississippi	710
21	North Carolina	293	Kentucky	394	Oklahoma	693
22	Louisiana	271	Michigan	387	North Dakota	667
23	Washington	271	Washington	322	South Carolina	653
24	South Dakota	270	Nevada	297	Arkansas	609
25	Oklahoma	264	Virginia	284	Florida	515
26	Alabama	262	West Virginia	261	California	458
27	Arkansas	234	Oklahoma	249	Louisiana	287

Rank	Milk cows 2 years and over		All sheep and lambs		Number of pigs saved[1]	
	State	Number (thousands)	State	Number (thousands)	State	Number (thousands)
28	Maryland	230	Wisconsin	246	Colorado	272
29	Georgia	228	Pennsylvania	235	Oregon	271
30	Idaho	219	Tennessee	188	Maryland	265
31	Florida	213	New York	158	Montana	259
32	Oregon	170	Louisiana	86	Washington	228
33	New Jersey	136	North Carolina	51	Idaho	212
34	West Virginia	135	Mississippi	48	New York	172
35	Colorado	127	Arkansas	42	New Jersey	133
36	South Carolina	118	Maine	38	Massachusetts	128
37	Maine	108	Maryland	30	West Virginia	125
38	Utah	106	Alabama	22	Utah	92
39	Massachusetts	100	Georgia	18	New Mexico	73
40	Connecticut	97	New Jersey	16	Delaware	59
41	Montana	80	Massachusetts	11	Wyoming	45
42	New Hampshire	60	South Carolina	11	Arizona	36
43	Arizona	54	Vermont	11	Maine	31
44	New Mexico	43	Connecticut	7	Connecticut	22
45	Wyoming	31	Florida	7	Nevada	17
46	Delaware	28	New Hampshire	7	New Hampshire	17
47	Nevada	18	Delaware	5	Vermont	16
48	Rhode Island	15	Rhode Island	2	Rhode Island	12
United States		19,215		31,446		93,173

*ERS, USDA, *Livestock and Meat Situation*, March 1962.
[1] Total pigs saved from spring and fall pig crops.

Table 2. Rank of States in Number of Milk Cows and Sheep on Farms, January 1, 1962, and Pigs Saved, 1961

Cattle	Number	Calves	Number	Hogs	Number	Sheep and lambs	Number
1 Omaha, Nebr	1,933,707	1 So St Paul, Minn	331,794	1 St Louis Nat Stk Yds	2,605,910	1 Oenver, Colo	1 019,768
2 Chicago, Ill	1,917,215	2 Milwaukee, Wis	251,836	2 So St Paul, Minn	2,457,545	2 Fort Worth Tex	712,180
3 Sioux City, Iowa	1,519,326	3 Sioux City, Iowa	145,074	3 Omaha, Nebr	2,190,378	5 So St Paul, Minn	711,865
4 So St Paul, Minn	1,097,770	4 Houston, Tex	111,987	4 Sioux City, Iowa	1,919,256	4 Omaha, Nebr	693,087
5 Kansas City, Mo	996,416	5 Springfield, Mo	98,574	5 Chicago, Ill	1,686,700	5 Sioux Falls, S Oak	483,960
6 St Joseph, Mo	603,172	6 St Louis Nat Stk Yds	84,918	6 Indianapolis, Ind	1,555,036	6 Sioux City, Iowa	432,319
7 St Louis Nat Stk Yds	743,720	7 San Antonio, Tex	84,331	7 St Joseph, Mo	1,256,572	7 West Fargo, N Oak	364 140
6 Oenver, Colo	514,666	6 Clovis, N Mex	82,250	8 Sioux Falls, S Oak	871,159	6 St Joseph, Mo	349,536
9 Oklahoma City, Okla	496,457	9 Boston, Mass	75,129	9 Kansas City, Mo	670,234	9 Kansas City, Mo	305 625
10 Sioux Falls, S Dak	460,244	10 Louisville, Ky	74 247	10 Peoria, Ill	856,729	10 Ogden, Utah	290,413
11 West Fargo, N Oak	417,603	11 Oklahoma City, Okla	67,797	11 Cincinnati, Ohio	563,319	11 Chicago, Ill	261,078
12 Ft Worth, Tex	415,620	12 Ft Worth, Tex	67,695	12 Evansville, Ind	521,022	12 St Louis Nat Stk Yds	252,227
13 Indianapolis, Ind	366,429	13 Omaha, Nebr	57,579	13 Louisville, Ky	353,677	13 Wichita, Kans	223,975
14 Wichita, Kans	256,796	14 Kansas City, Mo	55,902	14 West Fargo, N Dak	296,040	14 Portland, Oreg	172,517
15 Amarillo, Tex	244,685	15 Billings, Mont	46,769	15 Denver, Colo	241,474	15 Billings Mont	143,747
16 Montgomery, Ala	230,743	16 Montgomery, Ala	42,516	16 St Louis, Mo	216,762	16 Oetroit, Mich	127,395
17 San Antonio, Tex	229,993	17 Amarillo, Tex	42,422	17 Milwaukee, Wis	216,317	17 Indianapolis, Ind	126,274
18 Louisville, Ky	223,202	18 Denver, Colo	38,622	18 Springfield Mo	209,741	18 Louisville, Ky	95,654
19 Milwaukee, Wis	223,119	19 Buffalo, N Y	32,903	19 Wichita, Kans	200,277	19 Oklahoma City, Okla	69,671
20 Detroit, Mich	220,966	20 Lancaster, Pa	32,770	20 Springfield, Ill	175,642	20 Cleveland, Ohio	86,097
21 Lancaster, Pa	199,866	21 Cincinnati, Ohio	30,925	21 Oklahoma City, Okla	175,219	21 Columbus, Ohio	79,665
22 Springfield, Mo	186,555	22 Nashville, Tenn.	30,666	22 Nashville, Tenn	173,264	22 Milwaukee, Wis	84,375
23 Cincinnati, Ohio	163,256	23 Indianapolis, Ind	28,125	23 Columbus, Ohio	164 210	23 Peoria, Ill	61,521
24 Memphis, Tenn	141,635	24 Richmond, Va	27,941	24 Muncie, Ind	153,657	24 Springfield, Mo.	56,389
25 Billings, Mont	126,646	25 Tulsa, Okla.	26,175	25 Memphis, Tenn	142,985	25 Cincinnati, Ohio	54,169
26 Evansville, Ind	124,958	26 Cleveland, Ohio	25,559	26 Cleveland, Ohio	140,916	26 San Antonio, Tex	50,355
27 Nashville, Tenn	122,482	27 St Joseph, Mo	25,045	27 Bushnell, Ill	119,106	27 Nashville, Tenn	38,124
28 Clovis, N Mex	121,341	28 West Fargo, N Oak	21,745	28 Richmond, Va.	118,135	26 North Salt Lake, Utah	26,440
29 Portland, Oreg	115,032	29 Knoxville, Tenn	20,498	29 Baltimore, Md	110,686	29 Stocktnn, Calif	25,619

Cattle	Number	Calves	Number	Hogs	Number	Sheep and lambs	Number
30 Cleveland, Ohio	112,313	30 Joplin, Mo	19,312	30 Joplin, Mo	101,494	30 Evansville, Ind	25,010
31 Baltimore, Md.	107,561	31 Ft Smith, Ark	19,246	31 Portland, Oreg	100,338	31 Lancaster, Pa	23,381
32 Ft Smith, Ark.	103,900	32 Portland, Oreg	19,171	32 Fort Worth Tex	97,714	32 Parsons, Kans	22,403
33 Ogden, Utah	98,638	33 Detroit, Mich	18,672	33 Lancaster, Pa	80,561	33 Spokane, Wash	19,457
34 Peoria, Ill.	96 326	34 Memphis, Tenn	16,283	34 Pittsburgh, Pa	72,921	34 Buffalo, N Y	13,798
35 Tulsa, Okla.	90,412	35 Evansville, Ind	15,934	35 Detroit, Mich	72,155	35 Muncie, Ind	12,640
36 Stockton, Calif	89,885	36 Ogden, Utah	15,058	36 Dayton, Ohio	48,241	36 Pittsburgh, Pa	11,777
37 Parsons Kans	56,852	37 Sioux Falls, S Dak	14,740	37 San Antonio, Tex	46,238	37 Joplin, Mo	8,958
38 Joplin, Mo	43 491	38 Chicago, Ill	14,351	38 Stockton, Calif	45,818	38 St Louis, Mo	7,290
39 Richmond, Va.	47,097	39 Baltimore, Md.	12,631	39 Tulsa, Okla	45,298	39 Richmond, Va	6,774
40 Houston, Tex.	40,7[illegible]9	40 Stockton, Calif	11,836	40 Parsons, Kans	38,051	40 Boston, Mass	4,883
41 St. Louis, Mo	33 446	41 Parsons, Kans	11,072	41 Buffalo, N Y	34 966	41 Baltimore, Md	4,619
42 Columbus, Ohio	33,302	42 Columbus, Ohio	10,923	42 Chattanooga, Tenn	28,148	42 Springfield, Ill	3,995
43 Spokane, Wash.	34 720	43 Chattanooga, Tenn	7,010	43 Ogden, Utah	24,228	43 Amarillo, Tex	3,316
44 Boston, Mass.	34,[illegible]3	44 N Salt Lake, Utah	8,621	44 Montgomery, Ala	23,755	44 Dayton, Ohio	2,720
45 Buffalo, N Y.	30,[illegible]3	45 Peoria, Ill	5,787	45 Spokane, Wash	21,930	45 Tulsa, Okla	2,632
46 Chattanooga, Tenn	26 043	46 Spokane, Wash	5 850	46 Boston, Mass	19,615	46 Knoxville, Tenn	2,582
47 North Salt Lake, Utah	23,453	47 Wichita, Kans	5,045	47 North Salt Lake, Utah	18,989	47 Montgomery, Ala	1,485
48 Muncie, Ind.	17,675	48 Pittsburgh, Pa.	4 654	48 Fort Smith, Ark.	13,950	48 Memphis, Tenn	1,252
49 Springfield, Ill	15,733	49 St Louis, Mo	3,032	49 Billings, Mont	13,373	49 Chattanooga, Tenn	1,108
50 Knoxville, Tenn	14 614	50 Muncie, Ind	1,358	50 Houston, Tex	2,255	50 Bushnell, Ill	890
51 Pittsburgh, Pa	12,905	51 Dayton, Ohio	918	51 Knoxville, Tenn	147	51 Fort Smith, Ark	515
52 Dayton, Ohio	9 075	52 Springfield, Ill	733	52 New York, N Y	148	52 Houston, Tex	250
53 Bushnell, Ill	1,237	53 New York, N Y	136	53 Amarillo, Tex	63		
54 New York, N Y	1,061	54 Bushnell, Ill	2				
Discontinued reports	2,248		210				8
Totals	15,810,785		2,301,795		21,510,390		7,581,906

*AMS, USDA Livestock Division
Receipts of hogs in interior Illinois 5 000 300
Receipts at concentration yards and packing plants in interior Iowa and southern Minnesota were Hogs 16 633 000 Sheep 1 001 400
Receipts at 8 southeastern packing plants located at Albany Columbus Moultrie Thomasville Ga Dothan Ala and Jacksonville Fla were as follows Cattle 145 357 calves 27 913 hogs 917 287 and sheep and lambs none
In addition to the above salable receipts of goats for 1961 were as follows Fort Worth 3 603 San Antonio 38 286

Table 3. Salable Receipts of Livestock at Public Markets, in Order of Volume, 1961*
(Based on reports submitted by stockyard companies)

	Cattle		Calves		Hogs		Sheep and lambs	
	1,000 head	Av live weight, pounds	1,000 head	Av live weight, pounds	1,000 head	Av live weight, pounds	1,000 head	Av live weight, pounds
January	2,118	1,030	668	218	6,793	238	1,454	102
February	1,862	1,023	609	213	6,025	233	1,239	105
March	2,118	1,025	712	208	7,144	234	1,482	104
April	1,947	1,018	581	223	5,946	238	1,417	102
May	2,240	1,019	589	241	6,568	243	1,547	98
June	2,262	1,018	585	249	8,008	248	1,440	95
July	2,083	1,017	544	243	5,153	243	1,311	94
August	2,317	1,004	871	234	6,106	235	1,498	93
September	2,193	1,002	688	218	8,189	232	1,484	94
October	2,322	1,007	752	216	7,271	233	1,609	96
November	2,154	1,015	693	214	7,380	238	1,394	98
December	2,007	1,027	811	207	8,734	240	1,284	100
Total	25,610		7,884		77,293		17,159	
Average		1,017		223		238		98

*SRS, USDA, Crop Reporting Board.

Table 4. Commercial Livestock Slaughter and Average Slaughter Weights, by Months, 1961*

Rank	Broilers produced: State	Number (thousands)	Turkeys produced: State	Number (thousands)	Chickens on farms[1]: State	Number (thousands)
1	Georgia	348,200	Minnesota	18,576	California	40,697
2	Arkansas	229,104	California	17,703	Iowa	24,331
3	Alabama	198,146	Iowa	9,823	Pennsylvania	19,133
4	North Carolina	183,200	Wisconsin	6,212	Minnesota	17,957
5	Mississippi	135,683	Missouri	5,690	Texas	15,874
6	Texas	123,043	Virginia	5,336	Georgia	15,330
7	Maryland	107,953	Texas	4,784	North Carolina	14,426
8	Delaware	90,430	Indiana	4,078	Indiana	13,856
9	California	63,091	Utah	3,834	Ohio	13,147
10	Maine	58,480	Ohio	3,621	Illinois	11,442
11	Virginia	52,331	Arkansas	3,178	Missouri	11,013
12	Missouri	42,600	North Carolina	2,765	New Jersey	10,925
13	Pennsylvania	38,849	Colorado	1,996	Wisconsin	10,211
14	Indiana	38,472	Oregon	1,789	New York	9,894
15	Tennessee	33,007	Oklahoma	1,654	Nebraska	9,708
16	Louisiana	24,959	Pennsylvania	1,651	Alabama	9,518
17	West Virginia	23,126	Nebraska	1,475	Mississippi	6,961
18	Wisconsin	20,459	Michigan	1,409	South Dakota	8,584
19	South Carolina	20,100	Illinois	1,343	Arkansas	8,046
20	Connecticut	19,966	North Dakota	1,229	Michigan	7,196
21	Kentucky	16,850	Kansas	1,180	Florida	7,078
22	Washington	15,970	South Dakota	1,062	Kansas	6,951
23	Ohio	13,456	West Virginia	945	Virginia	8,755
24	Florida	12,222	South Carolina	904	Tennessee	6,462
25	Oregon	11,619	New York	772	Kentucky	6,022
26	Minnesota	11,583	Kentucky	761	South Carolina	5,779
27	New York	8,469	Georgia	669	Washington	5,700
28	Massachusetts	8,075	Massachusetts	506	Maine	4,627
29	Oklahoma	7,047	Washington	487	Louisiana	3,701
30	New Hampshire	5,560	Alabama	328	Connecticut	3,622
31	Illinois	5,144	Connecticut	277	Oklahoma	3,481
32	New Jersey	4,700	Idaho	259	Massachusetts	3,152
33	Idaho	4,312	Florida	248	Oregon	3,108
34	Michigan	3,100	Delaware	246	North Dakota	2,595
35	Iowa	2,888	New Jersey	180	West Virginia	2,082
36	Utah	2,104	Maryland	178	New Hampshire	1,930
37	Nebraska	1,892	Mississippi	149	Maryland	1,770
38	Kansas	1,702	Tennessee	138	Colorado	1,696
39	Rhode Island	1,472	Arizona	107	Utah	1,678
40	Colorado	828	New Hampshire	88	Idaho	1,414
41	Vermont	583	Louisiana	62	Montana	1,163
42	Arizona	499	Maine	58	Arizona	1,031
43	Montana	- -	New Mexico	38	New Mexico	942
44	Nevada	- -	Vermont	38	Delaware	853
45	New Mexico	- -	Rhode Island	25	Vermont	803
46	North Dakota	- -	Montana	18	Rhode Island	391
47	South Dakota	- -	Wyoming	11	Wyoming	336
48	Wyoming	- -	Nevada	1	Nevada	82
Total		1,992,143		107,879		357,910

*SRS, USDA, Crop Reporting Board.

[1] Does not include commercial broilers

Table 5. Rank of States in Broilers and Turkeys Produced in 1961, and Chickens on Farms (excluding broilers), January 1, 1962*

State	Number of sheep shorn[1] 1849-58, 1,000 head	Number of sheep shorn[1] 1881, 1,000 head	Weight per fleece 1949-58, pounds	Weight per fleece 1961, pounds	Wool production 1949-58, 1,000 pounds	Wool production 1981, 1,000 pounds
Ohio	1,035	822	8 4	8 0	8,695	7,418
Ind	419	422	7 8	7 8	3,168	3,223
Ill	542	610	8 0	7 5	4,310	4,582
Mich	336	346	8 2	8 4	2,760	2,804
Wis	218	199	7 8	7 8	1,708	1,575
E N Cent	2,550	2,499	8 10	7 88	20,639	18,702
Minn	681	831	7 9	7 8	5,388	8,549
Iowa	953	1,409	8 0	7 5	7,618	10,530
Mo	852	661	7 3	7 6	8,225	5,054
N Dak	448	616	8 1	9 4	4,094	5,789
S Dak	935	1,604	8 0	9 8	8,402	15,747
Nebr	471	656	7 7	7 5	3,586	4,821
Kans	481	875	8 2	8 0	3,748	5,414
W N Cent	4,801	8,452	8 13	8 37	38,068	54,015
N Cent	7,350	8,851	8 12	8 12	59,707	73,717
Ky	574	423	8 6	8 7	3,771	2,834
Tenn	254	184	5 4	5 8	1,381	1,086
Ala	44	26	5 7	5 8	241	151
Miss	71	53	5 2	5 5	378	292
Ark	44	43	5 8	8 5	262	280
La	82	88	4 0	4 5	370	398
Okla	150	214	8 5	7 8	1,273	1,675
Texas	5,818	6,431	7 8	8 1	45,228	52,225
S Cent	7,044	7,472	7 52	7 69	52,803	58,939
Mont	1,512	1,581	9 8	10 2	14,887	18,180
Idaho	894	1,043	10 2	10 1	10,107	10,522
Wyo	1,873	2,081	10 5	10 5	19,596	21,933
Colo	1,246	1,721	9 1	8 9	11,381	15,266
N Mex	1,234	1,137	9 2	9 1	11,299	10,364
Ariz	397	523	7 3	6 7	2,895	3,509
Utah	1,282	1,178	9 8	10 0	12,121	11,706
Nev	424	275	9 3	9 2	3,943	2,525
Wash	292	313	9 2	9 2	2,705	2,870
Oreg	724	897	8 7	8 1	8,261	7,230
Calif	2,304	2,503	7 0	7 9	18,035	19,719
West	12,262	13,250	9 07	9 19	111,231	121,824
N Atl	432	425	7 43	7 26	3,211	3,096
S Atl	665	853	5 57	5 61	3,820	3,795
U S	27,774	30,751	8 31	8 50	230,872	261,370

*ERS USDA *The Wool Situation* March 1962

[1] Includes sheep shorn at commercial feeding yards

Table 6 Grease Wool Shorn by States and Sections*

Countries	Averages 1936–40	Averages 1951–55	1958	1961
North America[1]	500.0	320.0	310.0	345.0
Canada	15.6	7.8	7.6	7.8
Mexico	10.3	11.7	9.9	10.1
United States	470.6	298.1	293.0	325.0
South America	640.0	720.0	750.0	800.0
Argentina	411.0	393.0	420.6	465.0
Brazil	35.5	52.4	63.0	52.0
Chile	32.6	41.6	48.9	51.0
Falkland Islands	4.0	4.7	4.5	4.5
Peru	19.4	20.4	22.0	23.0
Uruguay	126.2	194.8	176.4	185.0
Europe	495.0	510.0	565.0	595.0
Bulgaria	27.9	30.4	36.5	44.0
France	43.0	52.2	60.6	66.1
West Germany	21.7	13.3	11.7	11.5
Greece	19.3	20.8	24.0	25.5
Hungary	13.0	9.8	16.1	18.5
Ireland	17.2	15.8	21.4	23.0
Italy	30.4	37.2	32.6	29.2
Norway	5.9	7.9	8.0	8.0
Poland	6.8	12.2	19.8	20.0
Portugal	16.3	22.4	24.2	24.3
Rumania	40.7	40.2	43.2	47.0
Spain	80.0	84.6	75.0	77.6
United Kingdom	110.1	99.0	118.7	125.0
Yugoslavia	34.7	35.2	31.0	32.0
U.S.S.R. (Europe and Asia)	310.2	437.2	700.0	760.0
Africa	355.0	370.0	395.0	380.0
Algeria	22.0	20.4	19.0	19.0
Egypt	7.5	7.5	5.2	5.2
Morocco	35.1	30.8	35.2	35.0
Tunisia	12.0	11.4	7.4	8.0
Republic of South Africa	272.0	288.0	313.0	300.0
Asia	375.0	415.0	485.0	505.0
Iran	[illegible]	38.2	44.0	35.0
Iraq	[illegible]	24.0	23.1	23.0
Syria	[illegible]	19.0	20.7	14.3
Turkey (Europe and Asia)	[illegible]	78.6	79.4	100.8
China, Mainland	[illegible]	92.4	135.0	150.0
India	[illegible]	72.0	74.0	75.2
Japan	--	6.0	7.6	6.1
Pakistan	[illegible]	30.0	35.0	35.0
Oceania	[illegible]	[illegible]	2,130.0	2,270.0
Australia	[illegible]	[illegible]	1,590.0	1,679.0
New Zealand	[illegible]	[illegible]	540.0	592.0
Total World	[illegible]	[illegible]	5,335.0	5,650.0

*Foreign Agr. Service, USDA, *Foreign Crops and Markets*, July 17, 1958, and *Foreign Agr. Cir.*, August 1961.

[1] Continent totals include estimates from minor producing countries.

Table 7. Wool Production in Specified Countries, Greasy Basis (million pounds)*

Year	Turkey	United States	Republic of South Africa	Basutoland	Total
1935-39 av [1]	15 3	16 8	4 8	6	37 7
1951-55 av [1]	16 4	13 9	5 0	1 2	36 5
1956[2]	19 4	18 2	5 4	1 1	44 1
1957	21 3	19 1	5 6	1 1	47 1
1958	21 4	20 8	6 0	1 1	49 3
1959	22 6	23 3	8 0	1 2	55 1
1960	21 6	24 5	8 7	1 2	56 0
1961	19 6	26 4	10 0	1 2	57 2

[1] Foreign Agricultural Service USDA *Foreign Crops and Markets*, January 29 1959
[2] Data for 1956 and later years from Livestock and Meat Products Division Foreign Agricultural Service USDA April 6 1962

Table 8. Mohair Production in Specified Countries, Greasy Basis (million pounds)

State	Number of goats clipped[1]		Av clip per goat		Mohair production	
	1955, 1,000 head	1961, 1,000 head	1955, 1955, pounds	1961, 1961, pounds	1955, 1,000 pounds	1961, 1,000 pounds
Texas	2,831	3,841	5 8	8 7	16,401	25,690
Arizona	42	59	3 1	3 5	130	208
New Mexico	40	48	4 2	4 9	189	235
Missouri	39	37	2 6	3 7	101	137
Oregon	22	20	4 0	4 0	86	80
California	7	7	3 8	4 4	27	31
Utah	3	4	3 3	2 8	10	11
Total	2,984	4,016	5 7	8 6	16,928	26,392

*Crop Reporting Board SRS USDA
[1] In states where goats are clipped twice a year the number clipped is the sum of goats and kids clipped in the spring and kids clipped in the fall

Table 9. Mohair Production, by States*

	Milk production per cow[1]			Total milk production[1]		
Rank 1961	State	1950-59, pounds	1961, pounds	State	1959-59, million pounds	1961, million pounds
1	California	8,463	10,130	Wisconsin	16,394	17,997
2	Arizona	7,332	9,500	New York	9,458	10,575
3	New Jersey	7,863	9,110	Minnesota	8,882	10,390
4	Rhode Island	7,683	9,000	California	6,954	8,236
5	Washington	7,171	8,550	Pennsylvania	6,130	6,897
6	Connecticut	7,026	8,550	Iowa	6,062	6,063
7	New York	7,180	8,440	Ohio	5,416	5,418
8	Wisconsin	7,346	8,410	Michigan	5,340	5,296
9	Idaho	6,975	8,320	Illinois	3,978	4,269
10	Massachusetts	7,070	8,300	Missouri	3,978	3,784
11	Michigan	6,829	8,250	Indiana	3,638	3,216
12	Utah	7,142	8,180	Texas	3,104	2,975
13	Minnesota	6,598	8,130	Kentucky	2,473	2,600
14	Ohio	6,519	8,050	Tennessee	2,349	2,347
15	Pennsylvania	6,738	7,820	Washington	1,788	2,026
16	Indiana	6,333	7,640	Virginia	1,985	2,024
17	New Hampshire	6,342	7,600	Nebraska	2,201	2,003
18	Maine	6,316	7,600	Kansas	2,301	2,001
19	Illinois	6,375	7,570	Vermont	1,690	1,878
20	Vermont	6,325	7,550	North Dakota	1,754	1,740
21	Nevada	6,421	7,530	Idaho	1,425	1,664
22	Delaware	5,805	7,400	North Carolina	1,640	1,613
23	Oregon	6,208	7,140	Maryland	1,420	1,543
24	Iowa	5,978	7,100	Oklahoma	1,700	1,488
25	Maryland	6,193	7,080	South Dakota	1,391	1,442
28	Colorado	5,857	6,930	Florida	881	1,298
27	Florida	5,172	6,750	Mississippi	1,415	1,271
28	New Mexico	4,723	6,420	New Jersey	1,147	1,168
29	North Dakota	5,029	6,350	Oregon	1,182	1,121
30	Nebraska	5,317	6,300	Georgia	1,137	1,023
31	Wyoming	5,458	6,280	Alabama	1,187	956
32	Kansas	4,963	6,100	Arkansas	1,182	940
33	Virginia	5,054	6,060	Louisiana	792	887
34	Oklahoma	4,258	6,000	Colorado	887	825
35	North Carolina	4,875	5,930	Massachusetts	788	780
36	Montana	5,216	5,920	Utah	704	769
37	South Dakota	4,639	5,910	Connecticut	726	752
38	Missouri	4,811	5,760	Maine	675	714
39	Texas	3,912	5,380	West Virginia	782	640
40	Kentucky	4,308	5,200	South Carolina	581	540
41	West Virginia	4,358	5,120	Arizona	349	475
42	South Carolina	4,091	5,090	Montana	514	450
43	Georgia	3,903	4,940	New Hampshire	370	388
44	Tennessee	3,934	4,800	New Mexico	222	263
45	Arkansas	3,529	4,350	Delaware	196	185
46	Alabama	3,584	4,000	Wyoming	215	182
47	Louisiana	2,766	3,840	Rhode Island	135	126
48	Mississippi	2,932	3,620	Nevada	90	113

*Crop Reporting Board SRS USDA

[1] Excludes milk sucked by calves

Table 10. Rank of States in Milk Production per Cow and Total Milk Production, 1961, and Averages for 1950-59*

Year	Number of milk cows on farms[1]	Production per milk cow[2]		Total milk production on farms[2]	
		Milk	Milkfat,	Quantity,	Per capita,
	thousands	pounds	pounds	million pounds	pounds
1946	24 089	4 886	194	117,697	832
1947	23 329	5 007	199	118 814	810
1948	22,336	5 044	200	112 671	788
1949	22 024	5,272	209	116 103	778
1950	21 944	5 314	210	116 602	769
1951	21 505	5,333	210	114 681	743
1952	21,336	5 374	210	114 671	730
1953	21,691	5,542	215	120 221	753
1954	21 581	5 657	219	122,094	752
1955	21,044	5 842	225	122 945	744
1956	20 501	6 090	233	124 860	742
1957	19 774	6,303	240	124 628	728
1856	18,711	6 505	250	123 220	708
1959	17,901	6,815	257	121 989	689
1960	17 543	7,000	263	122 803	883
1961	17 396	7 211	270	125 458	686

*Crop Reporting Board SRS USDA

[1] Average number on farms during year excluding heifers not yet fresh

[2] Excludes milk sucked by calves and milk produced by cows not on farms

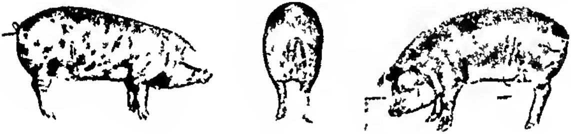
Table 11. Milk Cows and Milk Production on Farms United States 1946 61*

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
1955	9,181	8,865	10,433	11 087	12,902	12 409	11,352	10,425	9 459	9,166	8,583	9 083	122,945
1856	9,603	9,539	10,839	11 270	12 626	12,393	11,367	10,465	9,465	9,300	8,730	9,243	124 860
1957	9,711	9,337	10,807	11 269	12,862	12,296	11,360	10,385	9,362	9,279	8,712	9 248	124,628
1958	9,722	9,201	10 613	11,009	12,386	12,067	11,101	10,180	9,357	9,352	8,889	9 383	123 220
1959	8,730	9,208	10,623	11,005	12,230	11,748	10,773	9,963	9,316	9 240	8,778	9,375	121,989
1860	8,822	8,618	10 684	11 004	12,224	11,721	10,728	9,971	9,278	9 341	8,948	9,484	122,803
1961	8,862	9 438	10,931	11,200	12,375	12,039	11,057	10 270	9,621	9,872	9,219	9,772	125 456

*Crop Reporting Board SRS, USDA

SLAUGHTER BARROWS AND GILTS
U. S. Grades

U. S. NO 1



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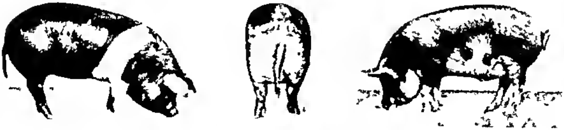


U S NO 3

MEDIUM

SLAUGHTER STEERS
U. S. Grades

PRIME

CHOICE

GOOD

STANDARD

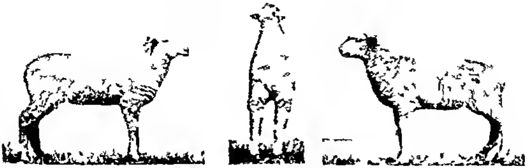
UTILITY

SLAUGHTER LAMBS
U. S. Grades

PRIME

CHOICE

GOOD



UTILITY

This glossary is not meant to be a substitute for a dictionary, nor for discussions presented in the body of the text Rather, "working definitions" of some of the terms which may be new to some students are given Definitions other than those given for each term might be equally accurate and complete Refer to Index for terms not given here

Abomasum—The fourth compartment of the ruminant stomach where enzymatic digestion occurs Often called the "true stomach"

Absorption—Movement of nutrients through the wall of the gastrointestinal tract and capillary walls into the circulatory sysem

Alveolus—A hollow follicle of cells In the case of mammary tissue the cells lining the lumen of an alveolus manufacture milk and secrete it into the lumen

Antibiotic—A compound that inhibits life Each has some specificity, inhibiting only certain species or strains, such as certain kinds of bacteria

Antibody—A chemical substance, in circulating fluids, colostrum, and milk, which contributes to immunity against a certain disease or infection

Antioxidant—A compound which prevents oxidation Used in mixed feeds to prevent rancidity or loss of vitamin potency

Bacteriostat—A compound which inhibits growth and reproduction of, or kills, certain bacteria

Barrow—A male pig castrated before puberty

Boar—A male pig which has not been castrated

Breed—A group of animals descended from common ancestry and possessing certain inherited characteristics which distinguish them from any other group

Breed type—Distinctive features in which one breed differs from another

Bull—A male bovine which has not been castrated

Calorie—The amount of heat required to raise one kilogram of water 1° Centigrade, or one pound of water approximately 4° Fahrenheit

Carbohydrate—A class of nutrients, each composed of carbon, hydrogen, and oxygen the latter elements present in a 2 1 ratio

Carcass—The major portion of a meat animal remaining after slaughter Varies among animals but usually the head and internal organs have been removed Skin and shanks are removed from cattle and sheep

Chromosome—A carrier of genes Physically, it is apparently a long protein molecule to which genes (nucleic acids) are attached

Colostrum—Milk produced by a cow, ewe, or sow the first few days after parturition It is thicker and darker yellow in color, and contains exceptionally high levels of certain critical nutrients as well as antibodies

Concentrate—A feed high in digestible energy and low in fiber

Conception—Union of ovum and sperm and implantation of the zygote to begin pregnancy

Connective tissue—A type of supporting tissue which is made of protein and especially strong. Some appears as long distinctive strands; other as a cementive mass between muscle cells.

Corpus luteum—Active tissue which develops on the ovary at the site where an ovum has been shed. If conception does not occur, the tissue gradually disappears. If it does occur the tissue becomes functional, producing progesterone.

Correlation—The tendency for the rate of change of one variable to be associated with the rate of change of a second variable.

Cow—A mature, female bovine, usually after one or two pregnancies.

Crossbred—An animal whose parents are of different breeds.

Crossbreeding—Mating animals of different breeds. A distinct type of outbreeding.

Crude protein—Nitrogen, present in feed, multiplied by 6.25. This factor is used because amino acids contain about 16 per cent nitrogen. Crude protein includes nonprotein nitrogen compounds.

Detergent—A compound which lowers surface tension. Used in mixed feeds because of apparent bacteriostatic effects. Also used for cleaning dairy equipment.

Digestion—Chemical and physical breakdown of nutrients in the gastrointestinal tract preparatory to absorption.

Digestion coefficient—The percentage of a nutrient that is absorbed from the digestive system.

Dominance—The tendency for one gene to exert its influence over its partner, after conception occurs and genes exist in pairs. There are varying degrees of dominance, from partial to complete to overdominance.

Dressing per cent—Carcass weight divided by live weight and multiplied by 100. Usually the cold carcass weight is used.

Elasticity of demand—The tendency of demand for a commodity to be influenced or changed by various factors. "Price elasticity" is the tendency of demand to change as price goes up or down. "Income elasticity" is the tendency of demand to change as the consumer's income goes up or down. Both are related to ability to buy.

Embryo—The developing young, during pregnancy, from soon after implantation to parturition.

Environment—All of the conditions to which an animal is exposed after conception.

Epididymis—A small, tortuous tube leading from the testicle. A site of sperm storage and maturation.

Estrogen—A female hormone which promotes development of the female reproductive tract and mammary tissue.

Estrous cycle—Cycle of events from one "heat period" to the next.

Estrus—The time when a female is "in heat" and will readily breed. Also called estrus period.

Ewe—A female sheep of any age.

Family—A group of animals, within a breed, that usually trace to some noted ancestor.

Fat—A class of nutrients, each normally composed of glycerol and three fatty acids. The most potent energy source in rations. Contains the elements,

carbon, hydrogen, and oxygen, the hydrogen present in much higher proportions than in carbohydrate

Follicle—The growth which appears on the surface of the ovary late in the estrous cycle and which contains the developing ovum

Follicle stimulating hormone—A hormone, produced hy the pituitary gland, which promotes growth of ovarian follicles in the female and sperm in the male

Free choice—Refers to individual feeds being available to animals so they can choose the proportion of each they prefer

Gene—The simplest unit of inheritance Physically, each gene is apparently a nucleic acid with a unique structure It influences certain traits Sometimes called a trait determiner Pl —Genes

Genotype—The genetic make up of an animal A listing of genes carried by the animal, for one or several traits

Gestation period—The duration of pregnancy

Gilt—A female pig before farrowing Some use the term until the second farrowing

Grade—Any animal, not purebred, that possesses the major characteristics of a breed

Heifer—A female bovine before calving Some use the term until the second calving

Heiferette—Used to describe a heifer which has calved once, perhaps prematurely, then was 'dried up and fed for slaughter

Heredity—A study or description of genes passed from one generation to the next through sperm and ova The heredity of an individual would be the genes received from the sire and dam via the sperm and ovum

Heritability—The degree to which heredity influences a particular trait

Heterozygote—An animal whose genotype, for a particular trait or pair of genes, consists of unlike genes

Homozygote—An animal whose genotype, for a particular trait or pair of genes, consists of like genes

Hybrid vigor—The tendency of crossbred offspring to perform better, in certain traits, than the average of their parents

Inbreeding—Mating animals that are related Varies in degree depending on degree of relationship

Index—A total merit score, usually calculated for breeding animals The weight of each component of an index is usually determined by its heritability and economic importance

Ingesta—Contents of the digestive tract Includes feed, digestive juices, bacteria, etc

Lactation—The period of milk secretion Usually beg ns at parturition and ends when offspring are weaned or, in the case of dairy cattle, the animal is dried up

Luteinizing hormone—A hormone, produced by the pituitary gland, which causes rupture of ovarian folicles in the female and secretion of testosterone in the male

Meiosis—Cell division early in the reproductive process, as in the formation of sperm and ova in the testicles and ovaries Each pair of chromosomes, in

the cell being divided, separates and one member of each pair goes to each of the two new cells formed

Metabolism—Utilization of nutrients inside body cells Usually involves many chemical changes

Mitosis—Cell division during normal growth of tissue Each chromosome divides so resulting new cells each have a full complement of chromosome pairs

Monosaccharide—A single sugar molecule, a carbohydrate

Non ruminant—An animal without a functional rumen Sometimes called a monogastric

Nutrient—A chemical element or compound which is essential for normal body metabolism

Omasum—The third compartment of the ruminant stomach Contains a mass of suspended, parallel, rough surfaced leaves which grind ingesta to a fine consistency Often called the "manyplies"

Outbreeding—Mating animals distinctly unrelated, usually with diverse type or production traits Varies in degree, depending on degree of divergence in type or production traits *See* Crossbreeding

Ovary—Female sex organ which produces ova after sexual maturity Pl — Ovaries

Oviduct—Tube leading from each horn of the uterus to the corresponding ovary

Ovum—The female sex cell, produced on the ovary, and carrying a sample half of the genes carried by the female in which it was produced Pl — Ova

Parturition—The act of giving birth—calving lambing, or farrowing

Pedigree—A record of aocestors

Phenotype—The characteristics which an animal shows or demonstrates This includes both appearance and performance

Pituitary gland—A small endocrine gland, located at the base of the brain, which produces and secretes various hormones into the blood stream These hormones help to regulate various body processes

Primal cuts—The most valuable cuts on a carcass Usually includes leg loin, and rib

Progesterone—A hormone, produced by the corpus luteum on the ovary, which aids in maintaining pregnancy

Prostate gland—A gland which surrounds the neck of the bladder and the urethra in the male

Protein—A class of nutrients including amino acids which may be present in feeds individually or combined Contains the elements carbon, hydrogen, oxygen, and nitrogen

Proven sire (DHIA)—A bull with at least 10 daughters which have completed lactation records and which are out of dams with completed lactation records

Puberty—The time when sexual maturity is reached In the female, ova on the ovaries begin to develop In the male, sperm production is initiated in the testicles

Ram—A male sheep which has not been castrated

Random mating—Allowing selected animals to mate at random

Ration—A combination of feeds, perhaps mixed together, which are fed to livestock to meet nutrient requirements May vary in quantity

Reach—Difference between the average merit of a herd or flock, in one or several traits, and the average merit of those selected to be parents of the next generation

Recessive—The tendency for a gene to be overshadowed, in its influence on traits, by its partner, after conception occurs and genes exist in pairs *See* Dominance

Registered—An animal registered by the breed association

Registration certificates—Papers showing that an animal has been recorded by the breed association as a purebred

Repeatability—The tendency of animals to repeat themselves in certain performance traits in successive seasons pregnancies, or lactations

Reticulum—The second compartment of the ruminant stomach, where bacterial digestion continues Has a honeycomb textured lining, so often called the "honeycomb"

Roughage—A feed low in digestible energy and high in fiber

Rumen—The largest of the four stomach compartments in the adult ruminant and the one to which most roughage goes first The site of active bacterial digestion

Ruminant—An animal with a functional rumen compartment in the stomach, plus three other compartments

Scrub—An animal having little or no improved breeding or an animal of mixed, mongrel, or unknown breeding

Semen—A mixture of sperm and accessory fluids produced by the testicle and accessory organs and glands

Seminal vesicle—A gland attached to the urethra, near the bladder, and which produces fluids to carry and nourish the sperm

Shoat—A pig of either sex, usually between 60 and 160 pounds

Shrink—Loss in weight Usually used to describe weight lost when livestock is shipped Weights are usually taken under comparable conditions before and after shipping

Sow—A mature, female pig, usually after one or two pregnancies

Spayed heifer—A heifer whose ovaries have been removed or the oviducts leading to the uterus have been severed

Sperm—The male sex cell, produced by the testicle, and carrying a sample half of the genes carried by the male in which it was produced Pl—Sperm

Stag—A male pig sheep, or bovine castrated late in life, after puberty and after secondary sex characteristics have developed

Steer—A male bovine castrated before puberty

Strain—A group of animals within a family A term of varying usage, some times used instead of family

Surfactant—*See* Detergent

Testicle—Male sex organ which produces sperm after sexual maturity Pl—Testes or testicles

Therm—1000 Calories

Uterus—The female reproductive organ where an embryo develops

Vas deferens—Tube connecting the epididymis of the testicle to the urethra.

Viscera—Usually refers to the organs of the abdominal cavity, removed at slaughter, including stomach, intestines, liver, and other accessory organs. Heart and lungs may also be included.

Vitamin—One of a class of nutrients, each required in small quantities and which usually function as a catalyst or catalyst component in body metabolism. Not needed as a source of energy or nitrogen.

Yearling—Normally an animal that is one year of age but not yet two.

Yield—1. Dressing per cent of an animal slaughtered. *See:* Dressing per cent.
2. Volume of milk produced per day or per lactation.
3. Pounds of wool clipped per ewe.
4. Percentage of clean wool after scouring.

Zygote—A fertilized ovum.

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